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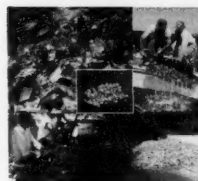
## *The Atlantic Pearl-Oyster*

# Marine Fisheries REVIEW

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On the cover:  
Pearls from the Atlantic  
pearl-oyster, *Pinctata  
imbricata*, surrounded by  
images of oysters on the  
sea floor, harvesting, shuck-  
ing, and a midden of dis-  
carded shells. Photographs  
provided by L. B. León S.



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# History of the Atlantic Pearl-Oyster, *Pinctata imbricata*, Industry in Venezuela and Colombia, with Biological and Ecological Observations

CLYDE L. MACKENZIE, Jr., LUIS TROCCOLI, and LUIS B. LEÓN S.

## Introduction

Around the year 1500, discoveries by Spanish explorers of sources of pearls, gold, and spices in the New World were a powerful stimulus for Spain to expand

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**ABSTRACT**—In the 1500's, the waters of Venezuela and to a lesser extent Colombia produced more natural pearls than any place ever produced in the world in any succeeding century. Atlantic pearl-oysters, *Pinctata imbricata* Röding 1798, were harvested almost entirely by divers. The pearls from them were exported to Spain and other European countries. By the end of the 1500's, the pearl oysters had become much scarcer, and little harvesting took place during the 1600's and 1700's. Harvesting began to accelerate slowly in the mid 1800's and has since continued but at a much lower rate than in the 1500's. The harvesting methods have been hand collecting by divers until the early 1960's, dredging from the 1500's to the present, and hardhat diving from 1912 to the early 1960's. Since the mid 1900's, Japan and other countries of the western Pacific rim have inundated world markets with cultured pearls that are of better quality and are cheaper than natural pearls, and the marketing of natural pearls has nearly ended. The pearl oyster fishery in Colombia ended in the 1940's, but it has continued in Venezuela with the fishermen selling the meats to support themselves; previously most meats had been discarded. A small quantity of pearls is now taken, and the fishery, which comprised about 3,000 fishermen in 1947, comprised about 300 in 2002.

into the Americas. Samples of these resources, which Christopher Columbus and later crews brought back to Spain, so aroused public enthusiasm in Spain that navigators, explorers, and adventurers began to organize expeditions to seek the treasures of lands beyond the "Western Ocean." Columbus first saw the pearls in the Gulf of Paria, Venezuela, on his third voyage, where local Indians had brought them from the Caribbean coast of Venezuela located to the northwest (Mosk, 1934, quoted by Galtsoff, 1950b; Morison, 1942; Hanson, 1967; Wagner, 1992).

The Spanish subsequently organized harvesting programs for pearl oysters in Venezuela and Colombia and began to ship huge quantities of pearls to Spain and other European countries for ladies adornment. The first Spanish town in the New World was established in 1528 on the Venezuelan island of Cubagua to serve as a center for harvesting pearl oysters and collecting pearls. The pearls from Venezuela, whose northeast shores became known as the "Pearl Coast," were relatively small, weighing 2–5 carats, but they were harvested in the largest quantities of any location in the New World. Within a decade or two following the discovery of the Venezuelan pearls, the Spanish found pearls and developed programs to harvest them on beds around islands off the Pacific Coast of Panama (Galtsoff, 1950a; MacKenzie, 1999) and in the Gulf of California, Mexico (Townsend, 1892; Kunz and Stevenson, 1908). They also searched for pearls in what is now the United States, but found none in its marine environments (Kunz and Stevenson, 1908).

By the late 1500's, the pearl oysters in Venezuela and Colombia had become much scarcer as a result of intensive fishing by hundreds of divers (Landman et al., 2001). Documentations of the pearl production may be the first records of resource declines in any of the world's marine fisheries that were brought about by intensive harvesting stimulated by strong market demand. In this case, large beds of natural pearl oysters that had been scarcely harvested beforehand were harvested intensely, albeit by primitive hand methods, and the beds were slowly depleted.

In 1948, Paul S. Galtsoff of the U.S. Bureau of Commercial Fisheries (now the National Marine Fisheries Service, NOAA) spent 2 months on Margarita Island, Venezuela, at the request of the Venezuelan Government which wanted him to recommend measures for managing its pearl oyster industry. This followed his similar stay in Panama for the same purpose (Galtsoff, 1950a). Galtsoff (1950b) reviewed the history of the Venezuelan pearl oyster industry, made observations and recommended research and management strategies, and later described them in that paper. Nothing has appeared in the international literature regarding this fishery since his paper was published. The senior author visited Margarita Island from 20 to 31 January 2002 to determine the history of this fishery industry between 1948 and 2002, collect additional earlier historical material, and photograph pertinent scenes. L. Troccoli and L. B. León S. have had long associations with fisheries in the Margarita Island–Cubagua Island–Coche Island region and contributed to this

paper printed and verbal information about the fishery, the biology and ecology of the pearl oysters, and additional photographs.

### The Pearl Oyster in the Caribbean Sea

The species of pearl oyster in the Caribbean Sea is the Atlantic pearl-oyster, *Pinctada imbricata* Röding 1798. It ranges beyond the Caribbean Sea to as far north as North Carolina (Ruppert and Fox, 1998) and south to Brazil (Abbott, 1974). The main fisheries for it have been off the coasts of Venezuela and northeastern Colombia. In Venezuela, the harvesting has been centered on beds near the clustered islands of Margarita Island, Cubagua Island, and Coche Island, 12–18 km off its northern coast (Fig. 1). Colombia's pearl oyster fishery was 1,000 km to the west on beds off the Guajira Peninsula close to the Venezuelan border. Bohlander (1992) reported that the explorer Alonso de Ojeda, in about 1500, observed people fishing for pearl oysters in what is now Lake Maracaibo, Colombia, but pearl oyster harvests there have not been described elsewhere to our knowledge.

The shells (valves) of pearl oysters are somewhat similar to some other oyster species. Its left valve is more concave than the right, and it has a byssal opening, a structure not universal in oysters (Fig. 2). The valves, which rarely exceed 7 cm in length, have three sections: a periostracum, a prismatic layer, and a nacre layer (León et al., 1987). The color of the outer surface of the valves varies from white to bronze and occasionally to black (Cervigon, 1998). Owing to its relatively small size and because its valves are thin, Atlantic pearl-oysters have not been used in the mother-of-pearl trade, which deals in ornaments, knife handles, and buttons from the larger pearl oyster shells harvested off the west coast of North America and in Asia. By 1900, thousands of tons of the pearl oyster shells lay in heaps along the Venezuelan coasts and in smaller quantities on the Colombian coast, where they had been left for centuries by oyster shuckers (Kunz and Stevenson, 1908).

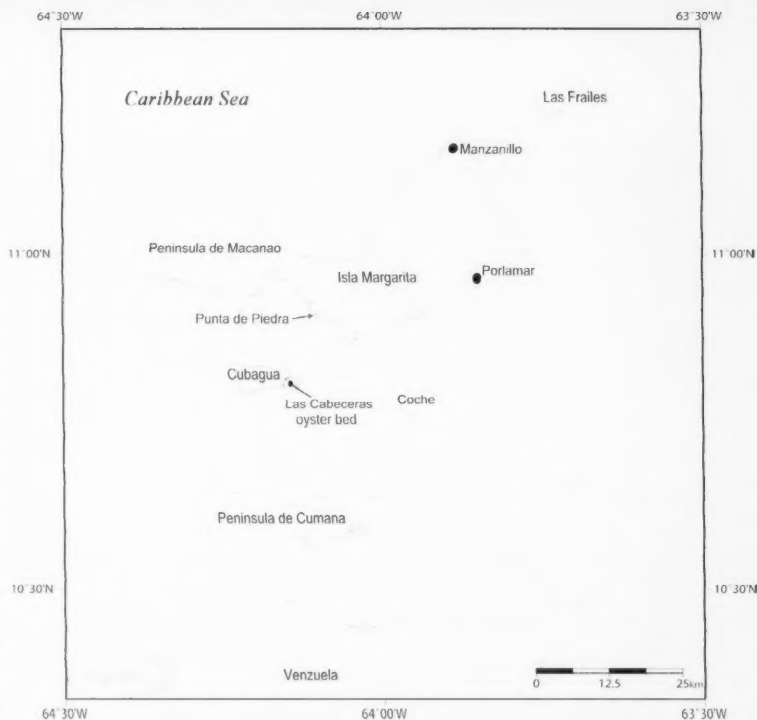


Figure 1.—Shaded area to right of Cubagua Island is the location of Las Cabeceras pearl oyster bed, the principal commercial bed in recent years. The Venezuelan mainland is in the foreground.



Figure 2.—The outer and inner surfaces of the valves of an Atlantic pearl-oyster, *Pinctada imbricata*.

### Pearl Oyster Biology

At the time of Galtsoff's (1950b) survey in 1948, knowledge of the spawning, setting, and growth of the pearl oyster was scarce, but it was known that

its larvae will set on hard objects with a clean surface, and growth of young pearl oysters is rapid. Some biological information relating to reproduction has since been gathered.

The Atlantic pearl-oyster is a protandric hermaphrodite. The small mature pearl oysters are males; the large pearl oysters are females. Their gonad surrounds their digestive diverticulum. Sperm and eggs are spawned into the water where fertilization takes place. The unfertilized eggs are  $47\text{--}50\mu$  in diameter; the sperm are  $60\mu$  long. In a laboratory study, the larvae resulting after fertilization took 20–25 days to grow to settlement size:  $215\mu$  (Ruffini, 1984) (Fig. 3, 4). Occurring in the tropics at lat.  $11^{\circ}\text{--}12^{\circ}\text{N}$ , this pearl oyster has a relatively long spawning season as do many tropical species. Reproduction takes place throughout the year, as shown by juveniles less than 5 mm long being present during all months, but setting is heaviest from June into November and December when water temperatures are highest. Water temperatures rise from about  $24^{\circ}\text{--}25^{\circ}\text{C}$  to  $26^{\circ}\text{--}28.5^{\circ}\text{C}$  during May to November, when the oysters spawn, and their condition index, determined by the volumetric method, drops from about 65–70% to 40–50%. This index is lowest during October and November. The Las Cabeceras bed (Fig. 5), the largest remaining bed, had the highest recruitment of pearl oyster spat of the beds surveyed. The oysters grow from settlement size to about 7 cm within 14 months (León et al., 1987).

### Ecology of Pearl Oyster Beds

The Atlantic pearl oyster inhabits clear waters (Cervigon, 1998). It does not occur where changes in temperature, salinity, and oxygen are large or on muddy bottoms (León et al., 1987). Its ready-to-set larvae attach with a byssus to hard substrates including other pearl oysters, rocks, dead coral and octocorals, other molluscan shells, and barnacles (Table 1). The oysters retain this attachment with several byssal threads throughout their lives unless, while seed, they are torn free by fishermen. Empty pearl oyster shells apparently do not accumulate beneath live pearl oysters as empty shells do in beds of the eastern oyster, *Crassostrea virginica*, in Canada and the United States. As an example, the oysters on the centuries-old Las Cabeceras pearl oyster bed near Cubagua Island rest on a base

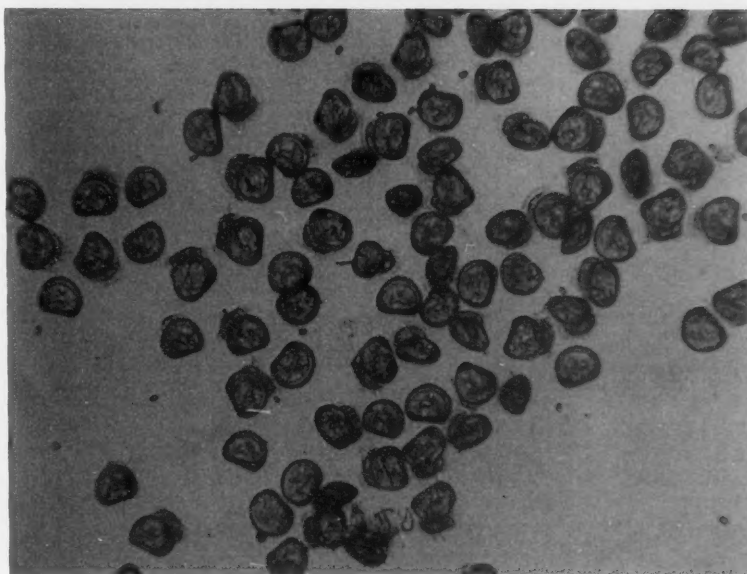


Figure 3.—Straight-hinge larvae of the Atlantic pearl-oyster, *Pinctata imbricata*.

Table 1.—Types of bottom on which Atlantic pearl-oysters, *Pinctata imbricata*, grow off the coast of Guajira in Colombia (Borrero et al., 1996).

1. Hard conglomerates or nodules in 1–3.5 m of water,
2. Plain bottom of sand mixed with hard substrate in 8–12 m of water,
3. Octocorals, gastropods, hard corals in agitated water in 6–12 m of water,
4. Dispersed octocorals and algae on sand bottom in calm water in 4–8 m of water (not many pearl oysters), and
5. Dense beds of octocorals in 3–9 m of water (not many pearl oysters).

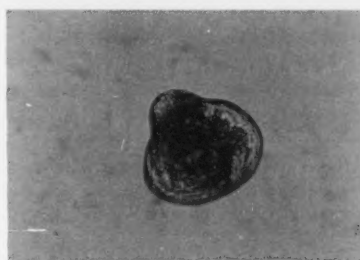


Figure 4.—Umbo larva of the Atlantic pearl-oyster, *Pinctata imbricata*.

of sand rather than a deep base of empty pearl oyster shells. In some locations, eastern oysters rest on bases of shells at least 7 m deep.

The relatively shallow regions (down to at least 20 m) surrounding the islands of Margarita, Cubagua, and Coche and those off the peninsula of La Guajira and in Chengue Bay, Colombia, become enriched with nutrients (mainly nitrates, silicates, and phosphates) from December through February each year, when extra strong easterly winds cause upwelling that brings waters from the nearby ocean depths into the shallows (Fig. 6). Water temperatures that usually are about  $26^{\circ}\text{--}28^{\circ}\text{C}$  in summer become  $2\text{--}3^{\circ}\text{C}$  cooler and the salinity increases by about 2‰ to nearly 36‰. The nutrients stimu-

late a large increase in phytoplankton that feeds fish (mainly sardines, *Sardinella aurita*) and mollusks (i.e. pearl oysters and mussels, *Perna perna*) that increase sharply in overall size but especially the sizes of their gonads throughout this period, in advance of spawning (León et al., 1987; Cervigon, 1998; Gaspar, 1999; Urban, 2000a). The fisheries for these resources benefit enormously (León and Millán Q., 1996).

The taxonomic list of mollusks associated with *P. imbricata* on and near the Las Cabeceras bed includes 89 species: 48 gastropods, 34 bivalves, 6 cephalopods, and 1 chiton (Fig. 7) (León, unpubl. data).

In 1948, northeastern Venezuela had about 76 identified pearl oyster beds, nearly all of which were too small for worthwhile harvesting. The beds were located in the same areas as they had been historically, i.e. between Margarita Island and the Peninsula de Araya on the

Venezuelan mainland, in depths from 4 to 20 m; several more beds were located off the north and northeastern shores of Margarita Island. The largest beds were at least 2.5 km across, and the most productive was the Las Cabeceras bed just east of Cubagua Island (Galtsoff, 1950b).



Figure 5.—Pearl oysters on Las Cabeceras bed off Cubagua Island, Venezuela.

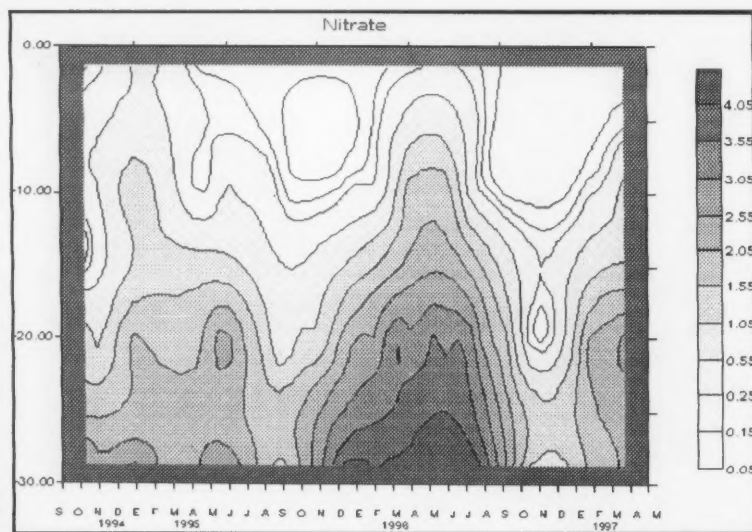


Figure 6.—Concentration (micromoles/liter) of nitrate in water at a sampling station off the south coast of Margarita Island, 1994 to 1997. Note the highest concentrations were during the months from February to August, the months of upwelling caused by consistently strong winds (from León and Millán Q., 1996).

In Colombia, pearl oysters were harvested from a bottom area that extended for 150 km just off the coast of Guajira. In 1994, a survey of the abandoned beds found concentrations of live pearl oysters that ranged from 0.05 to 2.77 oysters/m<sup>2</sup>. Pearl oysters larger than 5 cm (marketable size) ranged from 25% to 49% of the total oysters. In one location, of the 493 pearl oysters that were opened, 17 had pearls (3.4%), most of which were around 2.5 mm in diameter, while in another location 279 pearl oysters had 12 pearls (4.3%) about 1.5 mm in diameter. The pearls lacked the shape and luster required of good quality gems and were too scarce for commercial harvesting. Settlement densities of pearl oyster spat (juveniles), nonetheless, appeared to be sufficient to support a program of pearl culture which would include collecting spat on shells and other materials (Borrero et al., 1996).

Urban (2000b) observed aspects of *P. imbricata* reproduction in Chengue Bay, Venezuela, in 1997 and 1998. Chengue Bay is located on the north coast of Venezuela 150 km west of the Guajira pearl oyster area described by Borrero et al. (1996) and 14 km north northeast of the city of Santa Marta. Some natural stocks of *P. imbricata* are present in this bay. Urban (2000b) found the highest abundances of their larvae in November 1997 (1 collection: 0.8 larvae/m<sup>3</sup>) and in January through March, 1998 (1 collection each month: 1.0 larva/m<sup>3</sup>, average), but some larvae were collected in nearly every month. Spat were collected in bags of plastic mesh (onion bags) squeezed into net bags.

Urban (2000b) also identified two principal groups of predators consuming the pearl oyster spat: gastropods and crabs. The gastropods consisted of three species of the genus *Cymatium*, and the crabs belonged to three families: Portunidae, Xanthidae, and Majidae. The spiny lobster, *Panulis argus*, also preyed on the spat, but its abundance was lower than the other species. The surviving oysters grew to market size within 12 months. Urban (2000a,b) concurred with Borrero et al. (1996) that the Atlantic pearl-oyster produced sufficiently large numbers of spat to support a culture program, but he

expressed uncertainty about it because he observed a high mortality in the spat.

### Historical Methods of Harvesting Pearl Oysters

Through history, pearl oysters have been harvested by diving and dredging. Before 1500, the natives harvested pearl oysters by diving without gear, and this method continued to the early 1960's. Hardhat diving lasted from about 1912 to 1963. Dredging, which began in a rudimentary way in the 1500's, was intermittent over time, but done regularly throughout the 1900's and in 2000 and 2001.

### Pearl Diving

Descriptions of divers gathering pearl oysters are available from a few sources. Venezuelan Indians harvested oysters by diving to the bottom with a basket containing a weight and collecting them by hand. They dove without clothes, masks, or flippers. After 1–1.5 minutes on the bottom, they returned to the surface to breathe and deliver the pearl oysters they collected in the basket. They ate the oysters and kept the pearls found in some of them (Trevesan 1502 or 1504, quoted from Wilson, 1941).

Pearl oyster harvesting by enslaved Indians in the early 1500's was described by Oviedo y Valdéz (1535, quoted by Galtsoff, 1950b). From four to seven divers in each canoe paddled under the supervision of their master from Cubagua Island to places where the oysters were most abundant and anchored the boat. The divers each weighted themselves with a rock. Use of a rock enabled them to harvest longer, because they descended to the bottom more quickly. By thus expending less energy, they could hold their breath longer. The rock apparently was on a line and was retrieved by a tender in the canoe after the diver reached the bottom, though this can only be assumed as no description is available. Divers gathered as many oysters as they could in a bag they carried before having to return to the surface for air. The divers were forced to make many daily trips to the bottom.

A more recent and true story, famous on Margarita Island, relates to a diver, named Domingo, in about 1912. Do-



Figure 7.—Live animals and shells dredged from Las Cabeceras pearl oyster bed, February 1992.

mingo was harvesting pearl oysters on the Las Cabeceras bed off Cubagua Island when a sting ray, *Rajiformes*, stung his leg. He was able to rise to the surface and other divers brought him ashore. His poisoned leg swelled. A doctor told him the leg would have to be amputated or he likely would die. He did not want to lose his leg because he would not be able to work any more and his family would starve. Domingo and his wife prayed to their patron saint, Virgen del Valle, asking her to save his leg. They promised to give her a fine pearl if she did. His leg soon recovered, and, during the first day he returned to diving, he saw an extra large oyster on the bottom. He brought it to the surface, and, upon opening it, saw a large pearl. It was 17 mm long and was shaped like a leg except for 2 projections at one end (Fig. 8). His friends urged him to sell it to obtain a large amount of money. He was offered 100,000 Bolívars, which he refused saying, "No, the pearl belongs to the saint, and I will give it to her." He did and the pearl now rests on the crown of a statue of the saint in a church museum on Margarita Island (Cornieles<sup>1</sup>). The

pearl's unusual shape added substantially to local interest in the story.

In the 1930's and 1940's, divers went to the beds in small sailboats and sometimes were assisted by one or two tenders. Working without mask or flippers in 5–9 m of water, they swam to the bottom quickly and filled their bags with as many oysters as they could before returning to the surface to breathe. Tenders in the boats retrieved their bags of oysters from the bottom using a rope and emptied them. The tenders picked out the large oysters and tossed any remaining material overboard (Galtsoff, 1950b).

### Dredging

Galtsoff (1950b) described the pearl oyster dredge as a light, cast iron frame with a scraping blade to which a net bag is attached. The bag was maintained slightly above the bottom by 4–5 wooden sticks attached to its bottom to prevent it from being torn by rocks and corals. According to the present law (Art. 17, Chapter III, Ley de Pesca de Perlas, 1944), the size of a dredge cannot exceed 100 cm wide by 80 cm high. The dredges weigh 9–14 kg. The dredging boats that operated until the 1950's were about 6 m long and were propelled by sail (Fig. 9, 10). They had a crew of five men, four of whom

<sup>1</sup> Cornieles, Louis. First author's guide and translator. Porlamar, Isla Margarita, Venezuela. Personal commun., 2002.

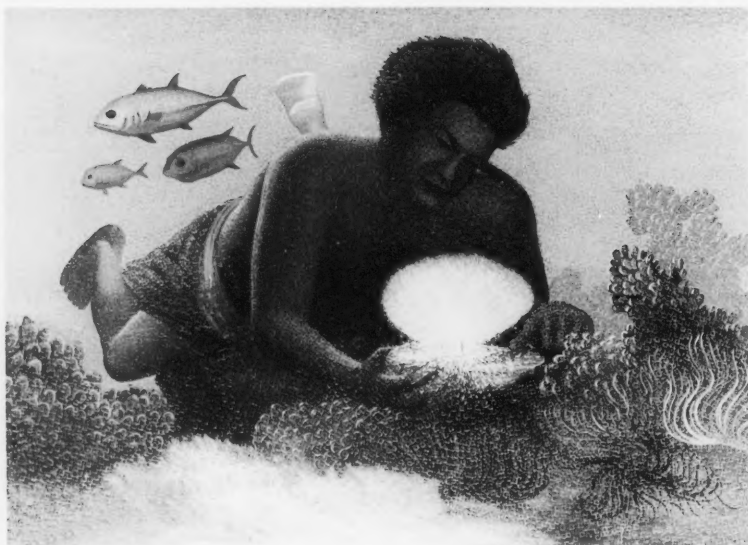


Figure 8.—Depiction of a diver finding a famous pearl, 17 mm long and shaped like a leg, destined as a gift to the saint of his church, whom he believed saved his poisoned leg; he actually opened the oyster in his boat. This painting and the pearl are on display in a church museum on Margarita Island.



Figure 9.—A sailing vessel used for dredging pearl oysters, pre 1950's.

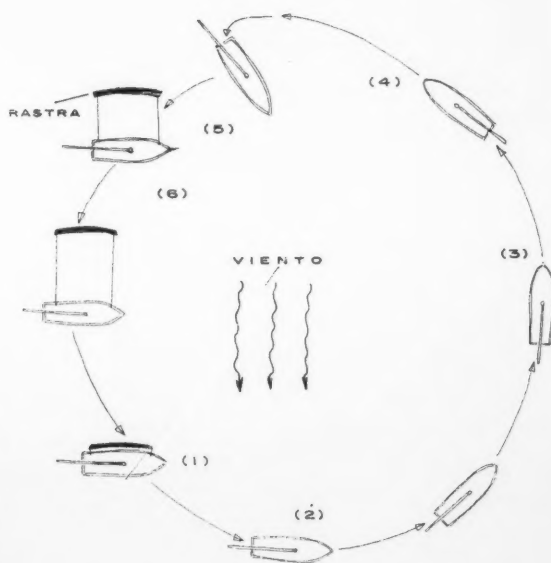


Figure 10.—The pattern sail boats traveled when dredging oysters. A boat towed dredges in locations 5 and 6, retrieved them at location 1, and then in locations 1–5 sailed back to dredging location (from Mendosa-Arocha, 1963). Note *rastra* means dredge and *viento* means wind.

tossed out and pulled up the two dredges and also culled and packed the oysters, while the fifth man handled the sail and rudder. The dredging boats harvested mostly on sand bottoms.

In 2002, observations were made on a boat dredging for oysters on the Las Cabeceras bed. The 6 m boat was propelled by an outboard motor and had a crew of three, all barefoot. The crew was allowed to tow one dredge (it had a 20 mm diameter towing rope) and could not use mechanical means to retrieve it. The crew located good harvesting locations by sighting and lining up prominent structures and points on land. They made several tows. Each time, they towed the dredge for 10–15 min, and two men pulled it up by hand for emptying while the third man handled the engine. The dredge usually had 1–1.5 bu of material in each lift: molluscan shells, pearl oyster “keepers” that ranged from 5 to 6 cm long, undersized pearl oysters attached by their byssuses to oysters and

shells, sand dollars (as large as 15 cm in diameter), mussels, at least four species of starfish, barnacles, bryozoans, octopi that were commonly 10 cm long, sea urchins, crabs, and gastropods. The crew dumped the material onto the floor of the boat, tossed the dredge over again, and then searched through the material for keeper pearl oysters. They pulled them from the undersized oysters and mussels, tossed them into a shallow plastic tub, which when full they emptied into sacks. The remaining material which comprised at least 95% of the original volume was tossed overboard. At the end of the fishing day, the boat returned to the beach where the pearl oysters were cooked and shucked. In the 1990's, oyster dredging boats had crews of four to five men (Fig. 11, 12).

### Hardhat Diving

The hardhat divers, who harvested pearl oysters from 1912 to 1963, ranged from 18 to 70 years old. They were taught how to use the gear and harvest oysters by relatives from generation to generation, but the training took only one day. The worst problem for a diver was leg cramps due to the cool water, and some older divers had heart attacks. A man needed an annual certificate of health, especially relating to his heart, to obtain permission from government officials to use the hardhat gear (Hernandez Salazar<sup>2</sup>).

<sup>2</sup> Hernandez Salazar, Leon Ramon. 82-year-old retired hardhat diver, Isla Margarita, Venezuela. January, 2002.

In the mid 1940's, the boats used in hardhat diving, all under sail, were each equipped with a hand-operated, two-cylinder piston air pump, a hardhat suit and helmet, and about 175 m of rubber hose and signal line. They had 7-man crews: the diver, two men who worked together turning the wheels that operated the pump driving air down to him, a man who relieved the pumpers, two linemen, and a cook (Fig. 13, 14). The original suits were made of rubber, but nylon was used after World War II. Imported from Europe and the United States, the suits were similar to jumpsuits with rubber at the waist as a belt. The first helmets had lead skirts that laid over the diver's chest and back. Together, they weighed 25 kg. The helmet and heavy lead boots he wore on his feet maintained him steadily on the bottom (Hernandez Salazar<sup>2</sup>).

The hardhat divers worked every day that had light to moderate winds. They harvested mostly on bottoms consisting of mixed corals, shells, and rocks as they had the better pearl oysters than bottoms consisting of sand. Upon reaching a harvesting location, the crew anchored the boat and helped the diver into his suit. He first slipped on wool pants, a long sleeve shirt, socks, and then the suit. Next he put on knee pads and leather caps over the ends of his fingers to protect them from cuts and abrasions, and finally he put on the helmet and boots (Fig. 15). The suit lasted about 3 months unless it was torn on coral sooner.

When the diver was ready, the air hose and signal line from the boat to the diver

were let out 46–50 m, with the extra hose and line remaining on the boat, and then the diver climbed onto a ladder and the crew lowered him to the bottom by the signal line and air hose. The diver jerked the line twice to signal he had reached bottom. He remained in the water harvesting for 2–3 hours without coming up for rest, food, or water. The helmet had a regulator valve that the diver could close to inflate his suit when he wanted to ascend to the surface (Hernandez Salazar<sup>2</sup>).

While harvesting, the diver could see objects at least 30 m away through the clear water including other divers; the divers had a personal code not to enter one another's harvesting areas. Harvesting pearl oysters was like picking fruit. The diver got down on one knee, picked up clusters of oysters, removed the "flowers" (seed), and put the large oysters in piles. When he yanked on the signal rope, the cook and standby man lowered a metal net to the bottom. The diver filled it with oysters, signaled, and the crew pulled it up to the boat, removed any mussels and stray seed oysters, and put the oysters in sacks. Three netfuls filled a sack (Hernandez Salazar<sup>2</sup>), and a sack contained 875–1,350 oysters (Galtsoff, 1950b).

Some crews brought food along with them, while others caught fish with hooks and lines while the diver speared some fish and gathered some mussels to eat. A boat brought the pearl oyster crews fresh water to drink. Each day, a diver spent 5–6 h on the bottom. The daily harvest



Figure 11.—Tossing out a dredge to harvest pearl oysters from Las Cabeceras bed, winter 1990's.



Figure 12.—Boarding a dredgeful of pearl oysters and other material from Las Cabeceras bed, winter 1990's.



Figure 13.—Crew pumping air to hardhat diver harvesting pearl oysters from the bottom below, probably 1940's (from Cervigon, 1998).

was 15–20 sacks of oysters/boat; the least a boat harvested was about 6 sacks/day. During a season, a diving crew harvested about 1,000 carats of pearls. Between harvesting seasons, the divers and crews caught fish to sell or found other odd jobs to earn money (Hernandez Salazar<sup>2</sup>).

#### The Discovery of Pearls in the New World

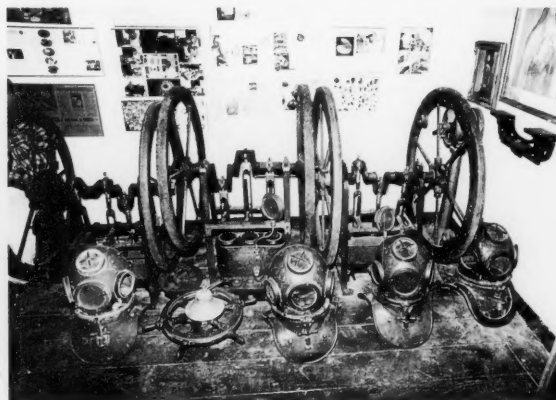
This sketch of the discovery of pearls in the Caribbean Sea is pieced together from several disparate, brief writings from the 1500's and later summaries of them in various publications which are cited in this section. The existence of pearls in the New World became known in Spain after Admiral Christopher Columbus' third voyage. On his first voyage, in 1492, he landed in the Bahamas and then explored Cuba and Hispanola (Haiti and the Dominican Republic). On his third voyage, in 1498, Columbus reached the South American mainland near what is now the Gulf of Paria near the Orinoco River in Venezuela and saw the natives

with pearls and gold. Women boarded his ship wearing necklaces of seeds interspersed with fine pearls. They said the pearls came from areas off the coast of the Peninsula de Araya in the Caribbean Sea as far as 100 km away. Columbus then sailed past Margarita Island, Cubagua Island, and Coche Island and went back to Hispanola, missing the sources of the pearls on those islands. In 1499,

Alonso de Hojeda was the first Spaniard to discover the pearl resources of the three islands (Galtsoff, 1950b; Morison, 1942, 1963; Cervigon, 1998; Landman et al., 2001).

In 1499, Columbus sent two of his ships back to Spain with some pearls. Later in 1499, Peralonso Niño, former pilot of Columbus' ships *Santa Maria* and *Niña*, captained a ship that sailed

Figure 14.—A display in Porlamar museum of hardhats and air pumps used by fishermen who harvested pearl oysters from 1912 to early 1960's.



from Spain to further explore what was to become the "Pearl Coast," i.e. collectively, Margarita Island, Cubagua Island, Coche Island, and the Peninsula de Araya. Niño traded bells, pins, bracelets, strings of crystal, rings, and other objects with the natives for their pearls, and in 1500 returned to Spain with between 11 and 44 kg of pearls. This trip by Niño was the first to the new continent that was economically successful. Trading in pearls soon expanded to become the business of directed pearl fishing and permanent settlements near the pearl oyster grounds were established (Galtsoff, 1950b; Morison, 1942, 1963; Cervigon, 1998; Landman et al., 2001).

### 1500's

#### The Founding of Nueva Cadiz: First Spanish Town

In 1509, King Ferdinand II of Spain and his representatives directed that a permanent settlement be established on Cubagua Island from where crews in canoes would go to the beds and harvest pearl oysters, and it would also serve as a collection center. From there, the pearls then would be sent to the ports of Santo Domingo, San Juan, and Havana, and then on to Spain (Fig. 16).

The Spaniards forced the Indians living on the islands into slavery, and made the men paddle canoes to the beds and dive for the pearl oysters. Whenever more divers were needed, the Spaniards brought slaves from the Venezuelan mainland and the Bahamas. The Taino Indians of the Bahamas were considered good harvesters because they had experience diving for queen conchs, *Strombus gigas*, one of their staple foods. The Spaniards paid as much as 150 ducats for each slave. In 1512, the first Spanish settlement, consisting of a group of huts made of palm trees, was established on Cubagua Island. In 1520, the native Indians on the Venezuelan mainland, located about 15 km south of Cubagua, rebelled in retaliation for raids by Spanish crews. This forced a temporary abandonment of the Cubaguan settlement by the 300 Spanish settlers because they were dependent on supplies, mainly food, from

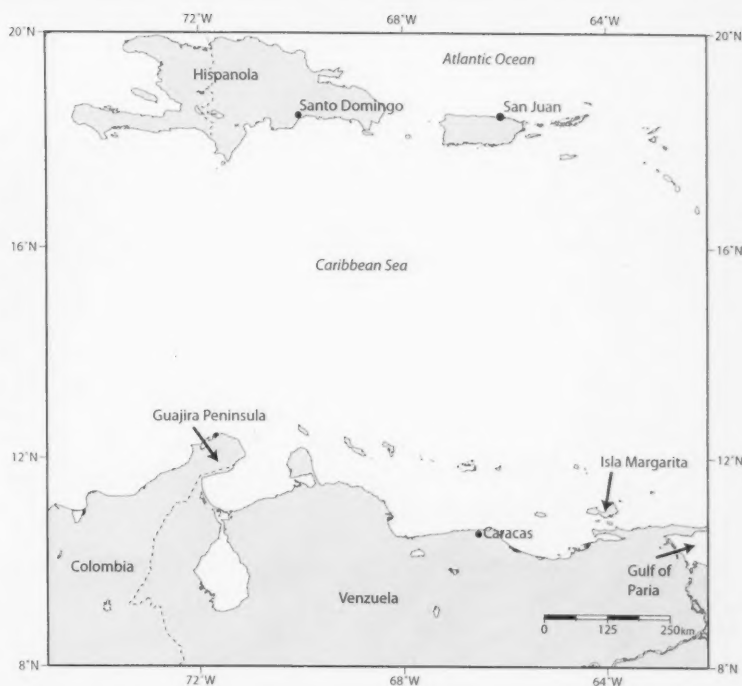


Figure 16.—The locations of the Guajira Peninsula, Colombia, and Margarita Island, Venezuela, where pearl oysters were harvested, and Santo Domingo and San Juan where pearls were sent before being sailed to Spain.

the mainland (Galtsoff, 1950b; Sauer, 1966; Cervigon, 1998).

In 1528, the settlement was restored with about 1,000 Spaniards. This was the first Spanish town founded in South America and the New World and was named Nueva Cadiz. Between 1530 and 1535, about 1,500 people lived in the town, and it enjoyed its greatest prosperity. The officials of Nueva Cadiz sorted the pearls into different grades, each being given a value in gold. The shades of pearls in the various grades could be white, yellow, or pink. Individual buyers selected the colors they liked best; any price differences between the different colors are unknown. They shipped an average of 800,000 pesos worth of pearls to Europe annually (Wagner, 1992; Cervigon, 1998).

From 1510 to 1537, the pearl harvesting spread. Initially concentrated on the oyster beds near Cubagua Island, the harvesting later expanded to other beds off

the south coast of Peninsula de Macanao on Margarita Island, off Coche Island, off the coast of the Peninsula de Araya on the Venezuelan mainland, and eventually off the coast of the Guajira Peninsula in Colombia (Landman et al., 2001). The Spanish government then issued special rules to maintain the fishery and the supply of pearls. Among them were: 1) Ranches (groups of huts for sleeping and for storing oysters and pearls) would be established near the pearl oyster beds, 2) each ranch would have a large box with two locks in which to safeguard the pearls, and 3) the ranches would obtain canoes, each armed and manned by no less than 12 slaves (Cervigon, 1998).

In 1541, Nueva Cadiz was destroyed by a hurricane, and the site was abandoned by 1545, mainly because the pearl oysters on nearby beds had become much scarcer owing to heavy harvesting. After that, Cubagua Island was gradually deserted (Wagner, 1992).

In about the year 1570, the Venezuelan State of Nueva Esparta, comprising Margarita Island, Cubagua Island, and Coche Island, was founded. Its official seal depicts a string of pearls and a canoe paddled by divers (Fig. 17) (Cervigon, 1998).

#### Slaves Diving for Pearls: Indians and Blacks

In the 1500's, local Indians were the first enslaved to dive for pearl oysters for the Spanish; Black slaves later replaced them. Spanish government officials recognized the necessity of protecting the pearl resources and preserving the lives of Indian divers, so they issued several "humanitarian" measures. They sought to limit: 1) pearl fishing to the summer so the divers could always work in warm water, 2) the work of divers to 4 h a day at depths not exceeding 14.5 m, and 3) the performance of extra work. They decreed that the divers should receive good food, a pint of wine a day, clothing, and hammocks for sleeping. Hammocks kept sleepers away from crawling insects, especially ants, and

also lizards, scorpions, and snakes, and they are more comfortable to lie on than the damp, bare ground.

However, these well-meaning measures remained on paper and not the slightest attempt was made to enforce them, because the overseers had little concern for the well-being of their slaves (Galtsoff, 1950b). A monk, named Bartholomew de Las Casas, who apparently was present at the sites, reported that the divers were treated harshly. Even when out of breath and fatigued, they were permitted only short respites between dives. On land, they were given small amounts of food (types of food not known), and they had to sleep on the ground. The slaves consequently lived only about a year after they were forced to dive for the Spanish (Chambers, no date; MacEoin, 1965).

During the 1500's, slaves of African origin began to replace the Indian slaves in many parts of the New World (Haverstock, 1988). The first notice of this was in 1526 when 30 black slaves were brought to Cubagua Island. A Royal Decree of 25 June 1558 prohibited the future use of Indians in pearl fishing and said that only blacks could be used for this purpose (Galtsoff, 1950b).

Mendez-Arocha (1963) quotes Francisco de Los Cobol who described some aspects of the pearl oyster fishery operations and the collection of pearls by the black divers. The slave owners rented them out to work in the pearl fishery. The boats, some with as many as 24 black slaves, left the beaches in the morning under the direction of slave masters, paddled to a pearl oyster bed, and harvested oysters. After a sufficient oyster supply was gathered, they returned to Cubagua Island and ate some food that had been prepared by slaves left behind on the beach. They then sat around piles of the pearl oysters and opened them with knives under the watchful eyes of supervisors whose job was to prevent stealing. Each had a small bagful of pearls at the end of the day. But stealing did occur and the slaves gave the stolen pearls to their owner. As a reward, their owner gave them a big party along with some clothes and shoes every 15–30 days.

#### Pearls Valuable to Spain

During the first half of the 1500's, large quantities of Venezuelan pearls were shipped to Europe (Landman et al., 2001), and, in 1527, pearl production reached its maximum, 1,380 kg (Cervigon, 1998). From 1513 to 1530, at least 118 million pearls were harvested near Cubagua Island. Seville, Spain, became the center of the pearl market, where Garcilaso de la Vega wrote that pearls from Venezuela and Colombia were so abundant "they were sold in a heap in the India House ... just as if they were some kind of seed." Portraits of European royalty at the time revealed many pearls embroidered on their dresses and in their headdresses, necklaces, and earrings (Landman et al., 2001). More natural pearls were harvested in Venezuela and Colombia at this time than elsewhere over any comparable period of time before or since (Donkin, 1998).

The richness of the pearl grounds in the Margarita Island–Cubagua Island–Coche Island area can also be seen from the following records of Royal Treasury officials on Hispanola; the Royal Treasury kept 20% of the pearls harvested in Venezuelan waters. In the month of January, 1529, at least 12,000 ounces (340 kg) of pearls, or the equivalent of 17 million carats (1 metric carat = 200 mg), were taken from the pearl beds off Coche Island. In June 1533, a vessel that sailed from Spain carried at least 340 kg of pearls. In July 1534, another vessel received for shipment 2 boxes of pearls from Cubagua Island; one contained 1,600 ounces (45 kg) of "common" pearls, while another contained 8,000 ounces (227 kg) of small pearls. On January 24, 1553, the royal officials at Cubagua Island gave several boxes of pearls to one vessel. The Treasury's record books showed that the value of pearls averaged more than 800,000 pesos annually up to 1530 (Galtsoff, 1950b; Wagner, 1992).

In the 26-year period between 1576 and 1602, twenty-one ships carrying pearls sailed from Margarita Island. The most important pearl merchants were in Santo Domingo and San Juan, while the



Figure 17.—The official seal of Nueva Esparta (comprising Margarita Island, Cubagua Island, and Coche Island), Venezuela, includes drawings of slaves paddling a canoe to or from the oyster beds and a string of pearls.

most important European markets were Seville and also Amberes, Spain; Venice, Italy; and Lisbon, Portugal (Cervigon, 1998).

### Pearl Oyster Bed Depletions

Oviedo y Valdés (1535; quoted by Galtsoff, 1950b) said the Spaniards were so aggressive in searching for pearls they were not content with just using divers to get them, so beginning in 1528 they used nets and crude dredges. They took such a quantity that the oysters were no longer found in abundance on the shallowest beds.

In the mid 1500's, many pearl fishermen and their divers moved from the partially-depleted Venezuelan beds to more recently discovered pearl oyster beds off the coast of the Guajira Peninsula in Colombia (Fig. 16, 18). The pearl oyster beds were a few hundred meters to several km off the coast, where the depths were from 3 to 10 m, and they covered a total area of about 68 km<sup>2</sup>. Individual beds ranged in size from a few square meters to 17 km<sup>2</sup>. Most were concentrated between the latitudes of the towns of Manaure and Arema. Little is known of the pearl oyster fishery in Colombia, except that it was considerably smaller than the one in Venezuela. Pearl oyster harvesting in Colombia went well at first, but the stocks declined fairly quickly, and thereafter it may have been intermittent. Middens containing shells of pearl oysters and other mollusks are scattered along this coast from Porpokin to Cabo de la Vela (Borrero et al., 1996).

Most harvesting crews returned to Venezuela, where, in 1576, new pearl oyster beds were discovered around Cubagua Island and Coche Island. About 2,000 black slaves were imported to exploit them (Cervigon, 1998).

By the late 1500's, Venezuelan pearl production had fallen sharply, largely due to a scarcity of oysters. The harvesting rate had been rapid. Each boat sometimes collected as many as 35,000 oysters in 2–3 weeks (Galtsoff, 1950b). Other reasons for the lower pearl production were: 1) the local Indians became deadly foes, 2) many Spaniards left Venezuela for the rich pearl oyster grounds in Panama and the Gulf of

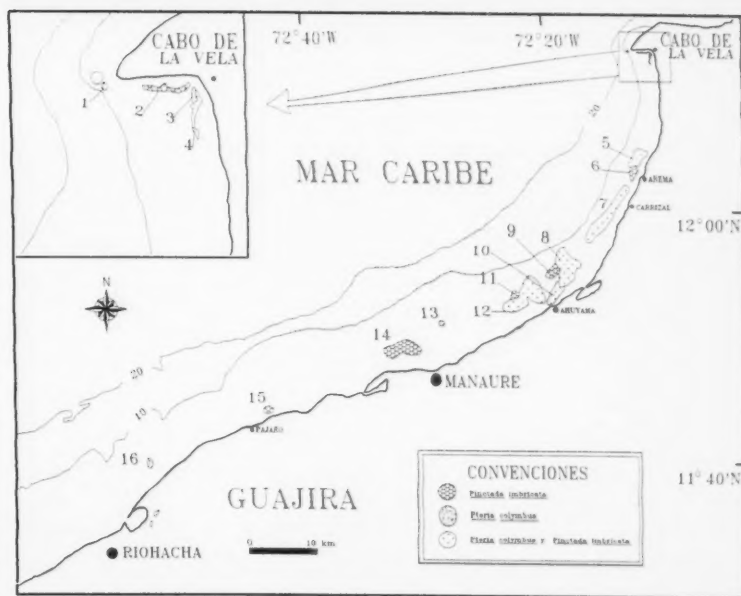


Figure 18.—Locations of oyster beds in the shallow zone off the coast of Guajira, Colombia, in 1994; depths are in meters; numbers to beds refer to specific names of beds (not given) (from Borrero et al., 1996).

California<sup>3</sup>, and 3) the market for natural pearls became weaker because imitation pearls were being manufactured in Venice and elsewhere in Europe, and diamonds had become a popular gem (Kunz and Stevenson, 1908; Galtsoff, 1950b).

### 1600's to Mid-1800's

Galtsoff (1950b) believed that after 1600 the pearl oyster fishery continued on a gradually diminishing scale. By the 1620's, only 130 black divers were left in the Margarita Island area, and by 1683, harvesting had practically ceased. Besides a scarcity of oysters, sea-going pirates made frequent raids to take any valuable products from Margarita Island, Cubagua Island, and Coche Island, making it difficult to continue pearling as a worthwhile industry.

The Spanish colonists eventually became aware of the principle of conserving natural resources. Mosk (1934, quoted by Galtsoff, 1950a) found one report written in 1613 that said it was fruitless to take pearl oysters from the beds near Margarita Island because they were full of small oysters and to take them would be a detriment to the interests of the pearl fishery and the Royal Treasury. Otherwise, little information exists about the pearl oyster industry in Venezuela during the 1600's, all of the 1700's, and the first half of the 1800's, perhaps because it was insubstantial. On a trip to Venezuela in the early 1800's, Humboldt (1814–29, quoted by Galtsoff, 1950b) said the pearl oysters had greatly multiplied after 2 centuries (1600's and 1700's) with little harvesting.

### 1845 to 1948

The pearl oyster fishery started up again in about 1845, and for several years thereafter an average of 45 kg of pearls/yr were landed. The oysters were harvested by divers and with dredges towed by sail boats. In 1853, the gov-

<sup>3</sup> These grounds, exploited after Balboa's discovery of the Pacific Ocean when he crossed the Isthmus of Panama in 1513, were producing well and were lucrative, especially after effective transportation of the pearls from the Pacific Coast to Europe was developed.



Figure 19.—Fleet of sail boats dredging oysters from Las Cabeceras bed, 1945 (from Cervigon, 1998).

ernment prohibited the use of dredges, and, by 1857, the landings were only slightly above 11 kg. Between 1857 and 1895, there were small intermittent pearl landings. An ounce (28.35 g = 192 carats) of good quality pearls there sold for US\$29–98 and inferior pearls for US\$16–20 (Quiévreux, 1900; Kunz and Stevenson, 1908).

In the 1890's, increased market prices for pearls stimulated a regrowth of the Venezuelan pearl oyster industry. This coincided with a period of prosperity in Europe and the United States. In 1895, the use of hardhat gear was tried for the first time near Margarita Island, but the divers and dredgers opposed its use. In 1899, Porlamar, the principal city of Margarita Island, had 7 licensed pearl buyers (Galtsoff, 1950b).

In the early 1900's, the Venezuelan government granted concessions to individuals and companies for harvesting pearls in defined areas and for limited periods, and it exacted a 10% royalty on the value of their pearl sales. It also prohibited oyster harvesting in some years when they were scarce. The total annual value of the pearls harvested was about US\$350,000 (Cervigon, 1998).

#### Large-scale Hardhat Diving

Beginning in 1912, the use of hardhat gear to harvest pearl oysters began on a large scale while harvesting by divers and dredgers continued in Venezuela. The hardhat divers worked at depths not exceeding about 16 m (Galtsoff, 1950b; Gaspar, 1999).

Cervigon (1998) provided some details about the pearl oyster fishery between 1918 and 1930. In 1918, it included about 400 boats, all using sail. There were 145 hardhat divers, about 150 dredging boats, and 100 divers. They sailed from ports on Margarita Island and from the port of Mariquada on the mainland. Most boats were about 7–7.5 m long, but some ranged to 9 m long, and they were under contract or under a manager. Individual managers had as many as 15–20 boats or 3–5 divers harvesting pearl oysters for them. The hardhat divers were controlled by 25 separate managers. Harvests were conducted from Mondays through Saturdays, and one could see the sails from the south shores of Margarita Island (Fig. 19). During the June to December off-season, pearl oyster harvesters

earned a living by finfishing and working ashore.

Cervigon (1998) said each boat sailed back to its port and its pearl oyster sacks were transferred to floating rafts that were anchored about 50 m from shore. Each raft had about six men and women who shucked the oysters with ordinary knives. Shucking often was done the day after the oysters were harvested, because they were easier to open and find the pearls. When the shuckers opened each oyster, they lifted the edge of the meat with their knife and looked for pearls located between it and the mantle. Another method was to spread out the meats and let them rot and dry before looking through them. It took them about 2 hr to shuck a day's pearl oyster harvest. An inspector on each raft made sure the shuckers did not steal any pearls.

Most pearls were sold in Porlamar. Through the years, the industry used various terminologies for the grades of pearls. In the mid-1900's, the pearls were grouped into four grades: 1) *de vistas* (symmetrical, good color and luster, and weighing more than 2 g and at least 7 mm in diameter), 2) *redondas* (similar to the *de vista*, but smaller and almost round),

3) barroques (irregularly shaped), and 4) mostacilla (poor quality and small). In addition to these grades there were seed pearls, 1–2 mm in diameter (Cervigon, 1998). Between 1918 and 1924, pearls sold in Venezuela for between US\$3.85–5.80/carat, depending on their shape and brilliance (Galtsoff, 1950b). In 1923, pearl production in Venezuela had a value of US\$500,000. In 1932, the pearl production was 437 kg (2,185,505 carats), but it declined afterward, except for 1943 when pearl production was 1,000 kg (4,998,257 carats) (Table 2).

Over the years, scarcities of pearl oysters on the beds limited harvests, but when the beds were left undisturbed the oysters became more abundant as a result of oyster larval settlement and growth. During the 1900's, government authorities used this knowledge to conserve the pearl oysters by closing the fishery for a season or two and then reopening it for a season or more. In 1936, the fishery was closed but, in 1937, it was active (Cervigon, 1998). (Note: the average landings over a period of years may have been about the same had the beds not been closed for a season or two).

### Pearl Industry in Colombia

In the first few decades of the 1900's, pearl oysters were harvested off the coast of Guajira, Colombia. Most harvesting was done in the offshore area between the towns of Pajaro and Cabo de la Vela. Men harvested the oysters by diving without masks or flippers, little different from 400 years before. Four or five divers in each small boat went out to the beds, harvested, and carried the oysters back to shore, where women shucked them and removed the pearls. Local merchants purchased the pearls and sold them in Europe, mainly in France and Germany. Pearl oyster harvests in Colombia ended in about 1940 (Borrero et al., 1996).

### 1940's

#### Harvesting Regulations

Galtsoff (1950b) said the harvesting of pearl oysters was regulated by the "Ley de Pesca de Perlas" established in 1944. It permitted harvesting for 4 months, between January 1 and April 30. Each

year, a resolution (in a compilation of laws) of the Margarita Island Ministry of Agriculture announced the opening of the season 60 days before the opening date (Article 5, Chapter II, Ley de Pesca de Perlas). The harvesting in any area or part of it could be ordered closed by this Ministry. The action would be promulgated upon the information the Ministry received from the fisheries administrator regarding oyster abundances on the beds.

The Ministry could also limit the number of diving boats operating, and it could temporarily prohibit their use (Article 8, Chapter II). It also had the right to limit the number of dredges used on each boat, but it was required by law to reconcile the interests of the various classes of applicants (Article 9, Chapter II). The law (Article 10, Chapter II) required that undersized oysters (under about 5 cm long), commonly called "conchas en flor" ("shells in flower"), be immediately returned to the bottom.

Some earlier laws relating to crew sizes remained in effect:

- Dredgers: No more than the master and six fishermen were allowed on a boat.
- Hardhat divers: Only one hardhat diver and six helpers were allowed on a boat.
- Divers: Only the master and six fishermen (inclusive of the free divers) were allowed on a boat.

#### Harvesting and Shucking

Galtsoff (1950b) and Cervigon (1998) described the pearl oyster fishery and the selling of pearls in the mid to late 1940's. The same three methods used for harvesting oysters earlier in the 1900's were employed. The number of boats or units harvesting can be estimated from the number of licenses issued: 412 for dredging, 28 for hardhat diving, and 1 for diving, but the numbers of boats harvesting each day were less than the number of licenses issued. The licenses were issued for each month and the number issued varied slightly by month. The 1945 season was the first that was limited to 4 months. Out of that 120-day period, the boats had about 60 days of effective oyster harvesting. The shorter

Table 2.—Pearl oyster production in Venezuela from 1919 to 1947 (Galtsoff, 1950b).

Year	Carats	Values
1919		82,875 <sup>1</sup>
1921–22		60,410 <sup>1</sup>
1932	2,185,505	336,440
1934	517,172	200,000
1937	418,207	157,202
1940	1,369,874	287,225
1943	4,998,257	773,840
1945	1,400,214	315,000
1946	1,281,899	500,000 <sup>1</sup>
1947	1,784,857	1,250,000

<sup>1</sup> According to Lopez (1950), the total yield of pearls during the 19-year period from 1921 to 1940 was 7,069,630 carats, valued at about US\$3,675,000. Values are in US\$.

season in 1945 allowed the oysters to become more abundant, so government officials allowed harvesting for 3 consecutive years, 1945, 1946, and 1947. In those years, 3,000 people were directly engaged in the pearl fishery. In 1947, the landings of oysters and pearls taken by each method were 330,034 sacks (877,427 carats of pearls) by dredging, 29,003 sacks (155,000 carats of pearls) by hardhat divers, and 100 sacks (300 carats of pearls) by divers (note: landings data reported by Galtsoff, 1950b and Cervigon, 1998 for the same years differed). The pearl oyster harvest was about 11,000 t of whole oysters.

Galtsoff (1950b) said the pearl oysters had become scarcer during 1947 and the administrators closed the beds in 1948. He thought the administrative control was beneficial, because it protected the oyster resource from excessive harvesting, but he recognized that the fishermen, shuckers, and their families, and the markets suffered, though, from the irregularity and uncertainty in their industry. But were the bed closings really beneficial when the fishermen left the undersized oysters on the beds anyway? Though it is difficult to know without controls, the average landings over time might have been at least as high had the seasons never been closed.

Galtsoff (1950b) and Cervigon (1998) said a complex scheme of dividing the proceeds of the fishermen's catch was governed by local tradition and custom. For a dredging boat: 1.5 shares went to the owner of the boat, 4 shares went to the owner of the dredges (2 for each dredge), 1.5 shares went to the master

who was responsible for selecting and finding the oyster beds, 1 share to each crewman, and 1 share to each of the two shuckers. But the division of proceeds was different in the case of a diving boat, 50% of the money from the sale of the pearls went to the person who owned or outfitted the boat; of this amount, he paid half of the license fee and gave 33% of the balance to the diver. The rest was his. The remaining 50% was divided among the crew. First, the cost of any food and half of the license fee was deducted; the balance then was divided into 14 shares, of which 6 shares were paid to the diver, and 8 shares were equally divided among the remaining crew.

Galtsoff (1950b) observed that most hardhat divers were middle aged. Younger men were reluctant to become professional divers. He believed if the trend continued the scarcity of experienced divers might lead to the complete abandonment of hardhat diving. His prediction was accurate because harvesting by hardhat diving did decline and it ended about 15 years later.

After harvesting, the pearl oysters were taken ashore to be shucked. Most were taken to Isla Caribe, where large shell heaps, some nearly 6 m high, laid about where shuckers had left them after many years of pearl oystering. The heaps had deep holes or trenches that had been dug by women and children who searched for pearls among the discarded shells. The shucking crews lived in small cabins on the shore during the oyster seasons (Fig. 20) (Galtsoff, 1950b). They removed most of the pearls as they opened them, but they also cooked the oyster meats in drums holding about 200 L of water to obtain any pearls that they may have missed. They stirred the boiling mixtures with paddles, and any pearls remaining in the meats were collected later from the bottom of the drums (Mendez-Arocha, 1963). The shuckers saved some oyster meats for preparing simple meals for themselves, but discarded most with the shells they dropped to the ground in front of their feet. As the shells and meats accumulated, hundreds of flies swarmed around each pile. The contrast between the beauty of the pearls and the



Figure 20.—Shucking pearl oysters on Cubagua Island, probably 1940's (from Cervigon, 1998).

miserable working conditions of the people who produced them was striking. The average yield per sack of oysters was 4.5 carats (1–2 marketable pearls) (Galtsoff, 1950b).

### Selling Pearls

The fishermen sold their pearls to licensed buyers in Porlamar or directly to tourists and visitors on Margarita Island (Fig. 21). At the beginning of the oyster harvesting seasons, there were nine operating buyers who opened their offices to appraise, sort, and purchase pearls. Fishermen brought the pearls to buyers' offices in a handkerchief or piece of cloth, and the pearls were spread on a green woolen cloth that covered a table. The buyer picked out and set aside the best pearls, and then, using a small, shallow silver scoop, he put the remaining pearls into a set of copper cups, 7–10 cm in diameter, with perforated discs containing holes that ranged from 1 to 6.5 mm in diameter (Fig. 22). The largest holes retained pearls of more than 8 grains (about 2.5 carats). The buyer weighed the groups of different sizes of pearls separately and quoted his prices for them (Fig. 23). He then poured each size grouping of pearls into small cotton

bags, or wrapped them in brown paper and stored them in boxes (Galtsoff, 1950b).

In April 1948, the buyers were paying an estimated 2.5 bolivars (US\$0.35)/carat for fairly good pearls. If the fishermen thought the price was too low, they visited other buyers for a better price. Whenever the price offered by all the buyers was unacceptable, the fishermen turned their pearls over to the fisheries administrator's office in Porlamar for official appraisal and disposal of the pearls through the Government Bank. The bank paid the value determined by official appraisers minus a 10% commission. The pearls became government property and the bank sold them when market prices were higher. In 1947, the bank purchased US\$250,000 worth of pearls (Galtsoff, 1950b).

Most pearls were exported to Europe, India, and China. Pink pearls, common in Venezuela, were highly desired in Europe, while India and China imported large quantities of tiny seed pearls. In India, many seed pearls were used to "treat" children's eyes. One or two seed pearls were placed under babies' eyelids for several minutes in the belief this made their eyes darker and shiny. Adult Indians



Figure 21.—Her Majesty Queen Sophia of Spain (R) and Flor Avila-Vivas (L), admiring collection of pearls in Ms. Avila-Vivas' museum shop, Porlamar, Margarita Island, November 1997.

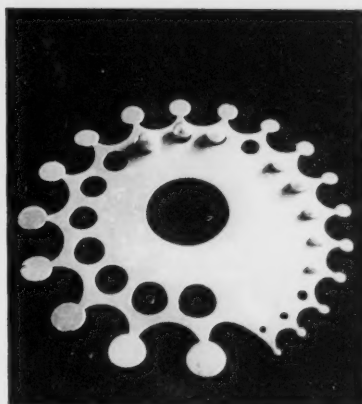


Figure 22.—A grader for sorting pearls into various size groupings.



Figure 23.—A buyer weighing some pearls in Porlamar, Margarita Island.

and Chinese ate seed pearls, whole and ground into powder, because of the belief they benefitted their health (Landman et al., 2001). Relatively small numbers of pearls and of only the highest quality were distributed in the United States through wholesalers in New York City; they wanted white pearls with high luster (Galtsoff, 1950b).

#### Venezuelan Pearl Oyster Industry, 1948–2002

During the 54 years between Galtsoff's stay in 1948 and 2002, the pearl oyster industry in Venezuela changed substantially. The pearl harvests nearly ended. This came about during the 1950's and 1960's, when a massive production of

saltwater cultured pearls, mainly from Japan, inundated the jewelry markets of the world. The cultured pearls were prettier, larger, and more nearly round than most natural pearls, and they sold at much lower prices than natural pearls.

By 1940, the Japanese culturists were producing about 10 million pearls annually (McClintock, 1994). In later years,

cultured pearls were produced by other countries bordering the western Pacific Ocean and some Pacific islands as well. As these pearls gained acceptance, the prices of natural pearls crashed and their industries in Venezuela and other countries became tiny remnants of what they had been (Ward, 1998). In addition, since the late 1960's, China has been producing substantial quantities of freshwater cultured pearls for jewelry markets, and they are much cheaper than the Asian saltwater cultured pearls (Ward, 1985). Freshwater pearl culture also has had limited success in the United States (Sitwell, 1985; Latendresse<sup>4</sup>).

After 1950, the price of Venezuelan pearls did not exceed US\$1.20/carat, and, in 1961, the price was US\$0.52/carat for the best quality pearls and US\$0.33/carat for the poorer quality pearls. Such prices contrasted sharply with those during the years 1918 to 1924 when they ranged from US\$3.85 to 5.80/carat. Venezuelan pearl production fell from 360 kg in 1947 (Galtsoff, 1950b) to roughly 2 kg in 1969 (Cervigon, 1998).

### Fishery Changes

The changes in the Venezuelan pearl oyster fishery featured:

- 1) the sale of nearly all oyster meats to people for food, to provide nearly the entire income for the fishery,
- 2) large declines in the numbers of oyster beds, boats, and fishermen and other industry people,
- 3) abandonment of diving, including hardhat diving, leaving dredging as the means of harvesting oysters,
- 4) a switch from sails to outboard motors to propel dredging boats, and
- 5) a shortening of the oyster season.

The remnant harvesters and shuckers were able to keep the industry going, although on a small scale, by selling the

meats beginning in about 1960. Soon afterward, government officials mandated that whole oysters had to be cooked when they were brought in from the beds. This was a sanitary measure as it was believed bacterial counts in live oysters would rise to unsafe levels in the warm air before people ate them. Cooking pearl oysters does not affect the luster of the pearls in them.

Some of the 76 beds, other than the Las Cabeceras and Los Frailes beds, Galtsoff (1950b) listed as surveyed in 1943 may still have some oysters in 2002, but they are too scarce to support commercial harvests. Perhaps the harvesting switch to dredging was a major cause in the decline in oyster abundances. Can abundances of pearl oysters that lie on a substrate of sand be sustained when fishermen dredge intensely for the market-sized oysters each year, or, were unidentified environmental factors part of the cause? These are questions for further research.

Fewer people now are involved in the fishery. The number fell from the 3,000 in 1947 to about 300 people (fishermen, shuckers, and vendors) in 2002.

In recent years, the government has restricted pearl oyster harvesting to January and February as a conservation measure, thus shortening the season from 4 to 2 months. It issues a license to each fisherman-owner of a dredging boat for US\$35 that allows him and his crew to harvest pearl oysters for a season. The license is issued to 30–45 boats. Each is limited to a harvest of no more than 10 sacks or 600 kg of oysters (about 10 bushels)/day.

During the 2000 season, estimated landings for all the dredge boats were roughly 500 t of live pearl oysters (about 20,000 bushels). They represented a tiny component of the landings of marine products in Nueva Esparta, only about 0.2% of the total. This contrasts with data in 1945, 1946, and 1947, when Galtsoff (1950b) said the pearl landings comprised from 6.8 to 14.1% of the landings.

### Status of Pearl Oyster Beds

The large Las Cabeceras bed and the small Los Frailes beds off northeastern Margarita Island have oyster abundances large enough for commercial harvesting.

The Las Cabeceras bed, which begins 200–300 m east of Cubagua Island, now is about 4 km long, 2 km across, and it is under about 8 m of water. The Los Frailes beds lie just west of the Los Frailes Islands under about 5.5 m of water.

### Las Cabeceras Bed

The oysters and other biota on the Las Cabeceras Bed are concentrated in dark patches, that stand out from the yellow sand between them when viewed through the clear water from a drifting boat. The patches are 18–25 m across and about half of the sand bottom is covered by the patches. The oysters are relatively young: Few are more than 18 months old because nearly all oysters above 5 cm long are harvested each season.

During recent harvest seasons, from 30 to 40 boats have been dredging oysters on the Las Cabeceras bed every day during calm periods. The boats are driven by outboard motors (40–75 hp) and are mostly 6–7 m long, while the largest are 8–9.3 m long. Each day, at about 3–4 a.m., 20–30 boats leave for the bed from 3 ports on Margarita Island and about 10 come from the mainland; the latter harvest illegally as by law they are restricted to beds near the Venezuelan mainland, but they find few oysters there. The Margarita Island boats reach the bed in about 30 min and each crew tosses out their one dredge to begin harvesting. The dredges do not have the wooden sticks on their bottoms to protect their meshes that Galtsoff (1950b) had described because this bottom is entirely sand. The fishermen probably dredge up and return nearly all the biota and shells lying on the bed at least once during every harvesting season.

### Manzanillo–Los Frailes Area

A tiny industry harvests and processes mussels and pearl oysters in the Manzanillo–Los Frailes area. During the oyster season, on every day with light to moderate winds, two boats from Manzanillo motor about 12 km to the beds off the Los Frailes islands. Each boat has about five men, all divers, who take turns harvesting mussels and oysters using hookah outfits (equipment that includes an air compressor on the boat and a long air hose to the face mask worn by the diver). Consider-

<sup>4</sup> Latendresse, G. Freshwater pearl culture in the United States. A talk presented at 92nd annual meeting of the National Shellfisheries Association. New Orleans, LA. April 13–17, 2003.



Figure 24.—Removing a sack of pearl oysters from tub of boiling water in which oysters were cooked for 20 min, Punta de Piedra, Margarita Island, February 2002.



Figure 25.—Dumping pearl oysters onto shucking table after they were cooked, Punta de Piedra, Margarita Island, February 2002.

able finfishing takes place in the area, so the harvesting is done by diving because it is believed dredging will degrade the fish habitat. The two boats harvest a total of 30 sacks of mostly mussels, but also some pearl oysters. They are sold to shucking groups in Manzanillo.

#### Processing and Marketing Oysters

Most oysters harvested from the Las Cabeceras bed are processed on the shores of Punta de Piedra, Margarita Island. Each boat has a location on the shore where its harvested oysters are cooked and shucked. The boats return to shore with their oysters at 7–10 a.m. The fishermen in each boat carry the sacks of oysters ashore and set them beside 1–2 tubs of boiling water heated by gas torches. They then wade in the water and anchor their boats perpendicularly to shore. Two members of each crew, using a 2 m stick, then lift one of the sacks into a tub and leave the oysters cooking for 20 min (Fig. 24). Using the stick, they then lift it from the tub and empty the steaming oysters onto a table (Fig. 25) surrounded by a crew of sitting shuckers (Fig. 26), and then continue handling the remaining oysters in the same manner. The shuckers typically are the wives and children of the fishermen. They open the oysters with



Figure 26.—Family group shucking pearl oysters in the shade, February 2002. This family group expressed good feelings about their continuing the long tradition (>500 years) of shucking pearl oysters.

kitchen knives and toss their meats into a common bowl in the center of the table. Every few minutes, the shuckers toss an oyster or mussel meat into their mouths to eat. A group of 8 shuckers opens a sack of oysters in 10 min.

In Manzanillo, the mussels and oysters are also cooked in tubs, shucked, and

the meats are sold. Any excess of live mussels and oysters is stored in baskets subtidally along the Manzanillo shore.

About 80% of the oyster meats on Margarita Island now are eaten in soups and stews, and some are creamed. The women shuckers take some meat home to eat, and the men take the bulk of it to



Figure 27.—A stand and manager with display of Atlantic pearl-oysters, *Pinctata imbricata*, and mangrove oysters, *Crassostrea rhizophorae*, on a beach, Porlamar, Margarita Island, February 2002. Both sold raw on the half-shell for \$1.30/dozen.



Figure 28.— Serving plate containing raw pearl oysters on the half-shell on a beach, Porlamar, Margarita Island, February 2002.

sell. Buyers pay the fishermen US\$2.00/kg for the meats, and sell them for US\$2.67/kg to local food markets, restaurants, and hotels. The meats are also peddled along the streets, where vendors add chile and onion and carry them warmed in a pan on their heads. Customers purchase them in plastic bags to eat as a snack. On swimming beaches, different vendors sell some pearl oysters along with mangrove oysters, *Crassostrea rhizophorae*, both raw on the half-shell for \$1.30/dozen, on paper plates to small family parties or groups of friends (Fig. 27, 28). People eat them and then toss the empty shells and plates into 50-gallon waste barrels. Fishermen harvest the mangrove oysters in La Restigna Lagoon on Margarita Island. The meats of raw and cooked pearl oysters are far more “chewy” and have a poorer flavor than mangrove oysters that are somewhat sweet. The remaining meats are ferried to the mainland where they bring about US\$4.00/kg.

### Selling Pearls and Shells

As they open the oysters, shuckers find a small number of marketable pearls and

save them in their pockets. The pearls are sort of a prize or bonus for the shuckers, who sell their small collections whenever they need some extra money. Each makes US\$80–100/year selling pearls to dealers, such as Flor Avila-Vivas<sup>5</sup>, the largest pearl wholesaler in Porlamar, to jewelry shops, to tourists on beaches, and some at their doors. In 2001, Ms. Avila-Vivas bought 2 kg of pearls from 25 to 30 families. They bring them to her in vials (about 150 pearls/vial), small match boxes, and little bags. She purchases the pearls by weight. A vial of pearls typically brings fishermen US\$6.67. She has little sale for tiny seed pearls (Fig. 29), but the shuckers insist she take them. They also bring her some blister pearls; such pearls are attached to the inside surfaces of oyster shells (Fig. 30). Ms. Avila-Vivas’ shop also cuts some shells that are especially shiny into round or oval shapes and sells them as pins and necklaces (Fig. 31). Shuckers bring her fewer pearls each year as the oyster stocks are believed to be dwindling.<sup>6</sup>

<sup>5</sup> Mention of trade names or commercial firms does not imply an endorsement by the National Marine Fisheries Service, NOAA.

### Recommendation for Oyster Bed Management

Galtsoff (1950b) recognized that oyster abundance would increase if shells were spread on the harvesting beds, and he described and photographed the large shell piles on Isla Caribe that were available for this. But he believed more biological information was needed to determine the periods of intense setting of oyster larvae and the locations where the larvae set most densely before this was done. He recommended studying the effects of oyster predators and possible parasites and diseases. The length of Galtsoff’s stay in Venezuela was too short for him to implement any of his recommendations. Some studies relating to biology were carried out later, though these may have been done without knowledge of Galtsoff’s recommendations. For example, the timing of oyster spawning and setting of larvae are now known (León et al., 1987), but shelling the beds was scarcely ever done.

<sup>6</sup> Avila-Vivas, Flor. Porlamar, Venezuela. Personal commun., 2001.



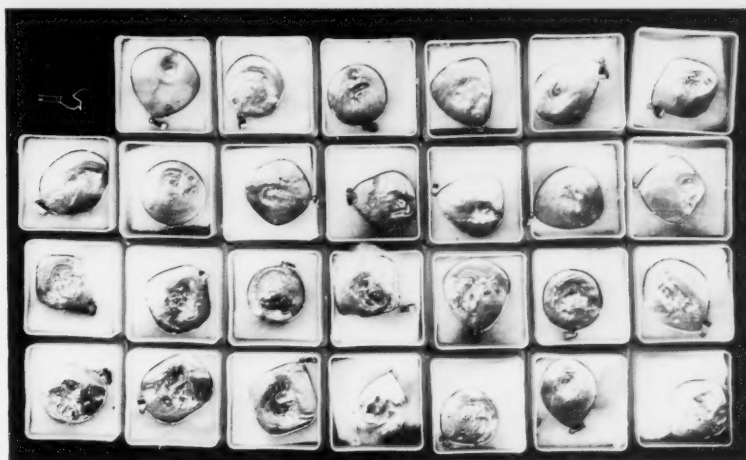
Figure 29.—Nearly every market-sized pearl oyster has tiny seed pearls, February 2002.



Figure 30.—Blister pearls attached to the shells of pearl oysters.

Figure 31.—Jewelry pins made from the shells (inner surfaces) of pearl oysters, displayed in a Porlamar museum, Margarita Island.

During the January–February oyster harvesting seasons, the oyster shuckers continue to discard the shells onshore. A program could be developed to store the shells and then spread them on the beds during the June–November period when the oyster larvae settle. To conserve or enhance the dwindling oyster stocks, perhaps some old shell piles have hard shells that could be used, but the oyster shell piles that Galtsoff (1950b) described in 1948 on Isla Caribe as being 6 m high may have few suitable shells. They have since been partially broken down by the sun and dissolved by rains and now are about 1.5 m high. During the summer months, the fishermen would not be able to transport and spread the shells as it would require too much time and expense when they are occupied with other types of work. This would probably have to be a government-sponsored project. Government officials could try to find the means to



have the fishermen store the shells and then have them barged to the beds and spread then.

In the Introduction, we said that by the end of the 1500's, Venezuelan pearl oyster stocks and production had declined sharply, and also noted that throughout the entire extent of this pearl fishery the shuckers have discarded the oyster shells. Had the harvesters con-

sistently spread all the shells back on the beds instead, we believe the oyster stocks would not have declined as much in the 1500's, and they would have been sustained better afterward. It could be said that overharvesting the oysters was not the entire problem, and that the oysters declined also because the fishermen reduced their habitat: the oyster shells on which the oyster larvae attach.

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# The Marine Life Fishery in Florida, 1990–98

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## Introduction

Tropical fish-keeping is the second most popular hobby after photography in the United States (PIJAC, 1999). More importantly, interest in home aquaria continues to grow. Industry growth has been especially prevalent for the establishment of "artificial reef" aquariums, which require colonization by invertebrates (Loiselle and Baensch, 1995), due to recent technological advances and breakthroughs in the care of such species. Marine aquariums in particular rely primarily on live specimens (fish and invertebrates such as plants, live rock<sup>1</sup>, live sand<sup>2</sup>, and crustaceans) collected from the wild. This is because only about a dozen marine ornamental fish species

are cultured commercially (Larkin and Degner, 2001). In the United States, the collection of marine ornamental species is restricted primarily to south Florida and Hawaii.

The marine life industry in Florida, as defined by the Florida Administrative Code (FAC), pertains to the nonlethal harvest of saltwater fish, invertebrates, and plants for commercial purposes (FAC Online<sup>3</sup>), primarily as ornamentals for the aquarium market. Products are landed live and sold to wholesalers, retailers, or direct to individual aquarium owners. Some products, such as sand dollars (family Mellitidae), are dried and destined for the shell/curio market. The vast majority of products, however, are destined for the hobby aquaria industry (PIJAC, 1999). Florida accounts for 95% of U.S. production (collection and culture) of tropical fish (saltwater and freshwater) (Watson and Shireman, 1996).

The State of Florida instituted a comprehensive data collection program, the Marine Fisheries Information System, in 1985 (FAC Online<sup>4</sup>). The data resulting from this system are commonly called "trip ticket" data, because the program requires that all landings of saltwater products intended for sale, barter, or trade be reported on a trip-level basis. The collection of trip ticket data for marine life began in 1990. Assessment of individual species and fishing effort are necessary to determine whether existing regulations are likely to be effective at maintaining the sustainability of the resources. To date, however, the data for marine ornamental species have not been studied.

Specifically, a thorough analysis of the marine ornamental species landings and effort data would aid in the development and analysis of regulatory options.

For example, the current moratorium in Florida on entrants into the marine ornamental species fishery until 2005, could produce a variety of economically beneficial effects by eliminating myopic fishing behavior. Short-run harvest decisions can produce a disregard for other fishermen, recreational divers, reef health, mortality rates, optimal harvest sizes, seasonal demand, etc. that can lower revenues. However, a moratorium cannot control fishing effort or participation rates (e.g. number of active fishermen). And, given the diversity of species collected, such a generic program could neglect the protection of species of specific concern. Moreover, the designation of 1997 as the "International Year of the Reef" brought international attention to the marine life collection industry. According to the World Resources Institute (WRI, 1998),

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**ABSTRACT**—The marine life fishery in Florida is defined as the harvest of live marine specimens (fish and invertebrate species including plants, and also live rock, and live sand) for commercial use, primarily as ornamentals for the aquarium market. This paper summarizes the regulatory measures that have been implemented and the data collected on 318 species between 1990 and 1998. Regional analysis shows the primary collecting areas, and seasonal analysis shows when the majority of landings occur. Statistics on the number of participants provide insight into the size of the industry.

<sup>1</sup> Live rock means rock with living marine organisms attached to it. (FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42.002(7). Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.)

<sup>2</sup> Live sand is no longer included in the regulations so there is no formal (legal) definition. In general, it refers to sand that has been exposed to seawater for a period of time such that it can more effectively support live organisms.

<sup>3</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42. Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

<sup>4</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68E-5. Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

nearly all reefs of the Florida Keys are at a moderate threat from human activities, including the overfishing of target species. In addition,

"At a minimum, over fishing results in shifts in fish size, abundance, and species composition within reef communities. Evidence suggests that removal of key herbivore and predator species may ultimately affect large-scale ecosystem changes. For example, removal of triggerfish has been linked with explosions in burrowing urchin populations, their prey, who subsequently accelerate reef erosion through feeding activities." (WRI, 1998:1).

To fill an informational gap that is needed for effective regulatory analysis, this paper summarizes the data collected by the State of Florida on 1) the harvest of live marine specimens for commercial use and 2) the participation by licensed and permitted fishermen. Following an overview of the regulatory environment, a description of the landings distinguishes between fish and invertebrates and, in particular, identifies statistics for live rock and live sand (which are reported in pounds rather than numbers).

In general, numbers of invertebrates landed greatly exceeds the number of fish landed. This is because, for example, hundreds of small snails can be harvested with a single scoop of a bucket. This harvesting method contrasts with the capture of fish species, which often requires diving gear and the use of slurp guns or nets to harvest an individual specimen. Another reason for distinguishing between fish and invertebrates is that fish prices per unit are, in general, higher.

Within the fish and invertebrate groups, data are summarized by common names. This decision was made in order to reduce the scope of the analysis since over 320 different species were landed during the study period. Furthermore, landings volume and value, average prices, and trip-level catch rates and revenue are only presented for the ten most valuable fish and invertebrate species groups, which are aggregated by common name.

## Regulatory Overview

The harvest of live marine ornamental species for commercial purposes is regulated in Florida by Chapter 68B-42 (formerly 46-42) of the Florida Administrative Code (FAC Online<sup>3</sup>). This chapter specifies the licensing requirements; identifies the "restricted species," which require an additional license to harvest; and establishes allowable gear use (including the use of nets, traps, chemicals, etc.) and harvest restrictions (including prohibitions on collecting certain species, quotas, closed seasons, closed areas, and allowable fish sizes). The major components of the current regulations are summarized below.

Recreational harvesters—for example, individuals wishing to stock their own aquarium—are subject to daily "bag" limits or quotas. For fish and invertebrates, the daily quota is 20 specimens (including no more than 5 angelfish and 6 colonies of octocorals) and no more than 1 gallon of plants (FAC Online<sup>5</sup>). Commercial harvesters have higher daily quotas for a number of fish and invertebrates, namely: butterflyfish, angelfish, porkfish, Spanish and Cuban hogfishes, starsnails, blue-legged hermit crabs, and giant Caribbean anemones (FAC Online<sup>6</sup>). To exceed the daily recreational bag limits, however, commercial collectors must have a current saltwater products license (SPL). To commercially harvest marine life specimens in particular, a marine life endorsement (MLE) is also required. During the 1998 session of the Florida Legislature, a moratorium on the issuance of new MLE's was passed, effective 1 July 1998 and was recently extended until 1 July 2005. In addition

to the SPL and MLE, a restricted species endorsement is needed to sell the majority of fish, invertebrate, and plant species (FAC Online<sup>7</sup>). These licenses and endorsements are issued by the Florida Fish and Wildlife Conservation Commission (FFWCC), which is the agency charged with managing the state's fisheries according to regulations passed by the Florida Legislature.

Aside from daily bag limits and annual permitting requirements, certain fish species are subject to size restrictions (FAC Online<sup>8</sup>). For example, butterflyfishes and several species of angelfish—including gray, French, blue, queen, and rock beauty—are currently subject to minimum and maximum length restrictions. Maximum lengths are also specified for gobies, jawfish, and Spanish hogfish, while spotfin hogfish are subject to a minimum length requirement.

Not all species may be harvested. The list of prohibited species includes longspine sea urchins, Bahama starfish, sea fans (*Gorgonia flabellum* or *G. ventalina*), all hard and stony corals, and all fire corals (FAC Online<sup>9</sup>). The prohibition on the harvest of sea fans and corals does not, however, apply to such organisms that are attached to legally harvested live rock.

Although the harvest of native live rock from state waters is now prohibited, live rock can be cultured provided that the rock is "of a readily distinguishable geologic character from rock native to

<sup>3</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Fish Chapt. 68B-42(2), Invertebrates Chapt. 68B-42(3), and Plants Chapt. 68B-42(4). Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

<sup>5</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42.005. Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

<sup>6</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42.006. Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

<sup>7</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42.003, 68B-42.009. Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

the area or be securely marked or tagged" (FAC Online<sup>10</sup>). In addition, live rock may only be harvested from submerged lands leased from the State of Florida if the individual has an Aquaculture Certificate issued by the Florida Department of Agriculture and Consumer Services and a Federal Live Rock Aquaculture Permit issued by NOAA's National Marine Fisheries Service.

Allowable gear restrictions regulate the use of nets (hand held, barrier, and drop), trawls, and slurf guns (FAC Online<sup>11</sup>). Barrier nets cannot exceed 60 feet in length, have a depth greater than 8 feet, and a mesh larger than  $\frac{3}{4}$  inch. Drop nets are also restricted to a mesh size of  $\frac{3}{4}$  inch and maximum dimension of 12 feet. Trawls, which can only be used to collect dwarf seahorses, must be towed by a vessel no longer than 15 feet (and at no greater than idle speed) with an opening no larger than 12 inches by 48 inches. Quinaldine (2-methylquinoline, CAS No. 91-63-4), a chemical used to briefly anesthetize fish and facilitate their capture, may be used only if the individual has a special activity license issued by the FFWCC (Rule 62R-4.004).

Finally, all collected marine life must be harvested live and the vessel must contain a continuously circulating live well, aeration, or oxygenation system (FAC Online<sup>12</sup>). Species may be collected from all state waters, excluding the U.S. Department of Interior's Biscayne National Park (unless permission is obtained from the park superintendent), and

adjacent Federal waters (FAC Online<sup>13</sup>). Harvest limits apply to species collected from all areas.

### Data and Methods

The Florida Department of Environmental Protection (FDEP), formerly known as the Department of Natural Resources, has been collecting data on the harvest of live marine ornamental products since 1990. The Marine Fisheries Information System is the data collection program maintained by the FDEP. These data are maintained and analyzed by the Florida Marine Research Institute (FMRI). Prior to 1990, landings data were collected only from individuals holding quinaldine permits. Given that the pre 1990 data exclude invertebrates, prices, and the harvest of fish without chemical use, these data are not analyzed in this report. All data described in this report were obtained from FMRI.<sup>14</sup>

The FDEP requires licensed wholesale dealers (i.e. buyers) to report dealer and harvester (collector) license numbers, the location of harvest, the species and quantity purchased, and the value of each transaction by species (Chapter 62R-5). Since these transactions typically occur immediately following the trip, these forms are referred to as "trip tickets." In the case of live marine ornamentals, the majority of collectors are also dealers that inventory product for a period of time before selling (Larkin and Degner, 2001). Thus, the trip ticket information most aptly reflects the total revenue received by harvesters for specimens that survive to the first point of sale. In addition, landings that are not sold, bartered, or exchanged (i.e. harvested for commercial use) are excluded from the data set.

The trip tickets also allow the collector to report the size of individual

specimens collected (e.g. small, medium, large) since there are size limits for some species. The size information is, however, not mandatory and is frequently unreported. Due to the scope of the data considered in this description (i.e. given the number of species, years, seasons, and areas), species size information is not incorporated into this analysis. It is important to note, however, that the size of wild-caught ornamental fish will vary depending on species, season, location, and sex of the fish. These factors can also affect specific characteristics of the fish, such as color. For many species, size and color differences translate into price differences.

The landings of the majority of marine ornamental species are measured in terms of the number of specimens collected live by the harvester. Landings of some species of invertebrates are, however, measured in pounds (e.g. live rock and live sand) and gallons (e.g. snails and plants). To facilitate comparisons between fish and invertebrates and among invertebrates, data is most frequently summarized by landed value (i.e. harvester revenue calculated from the quantities and prices reported on the trip tickets) vs. volume.

### Results

#### Industry Participants

The number of licensed marine life dealers increased significantly in the mid 1990's, but by 1998 this number had declined to the level observed in the early 1990's (Table 1). In 1998, there were 66 licensed dealers in the State of Florida. Individuals can be licensed as both a collector and dealer, and many hold both licenses (Larkin and Degner, 2001). Information on all other permits, licenses, and endorsements are also summarized in Table 1 for the 1990-91 to 1998-99 seasons.

The MLE is the only license/permit that applies exclusively to the marine life industry. The total number of MLE's increased from 1990 to 1997. In 1997, about 800 endorsements had been issued, whereas fewer than 200 were issued in 1990. The number of active marine life endorsements (i.e. endorsements with

<sup>10</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42.008(3) (a). Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

<sup>11</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42.007. Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

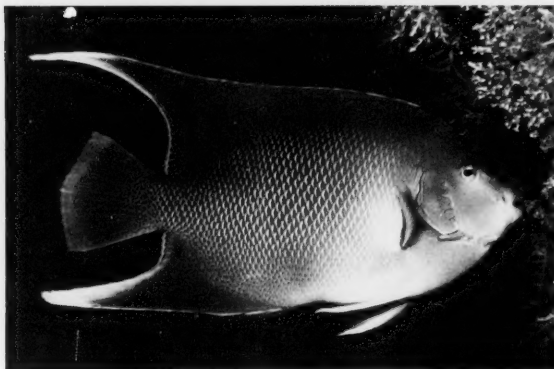
<sup>12</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42.0035. Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

<sup>13</sup> FAC Online. 2001. Florida Dep. State, Div. Elections, Tallahassee, Fla. Official publication, Florida Administrative Code annotated, available from LexisNexis, 701 East Water Street, Charlottesville, VA 22902, Chapt. 68B-42.0036. Available online at <http://fac.dos.state.fl.us/faconline/chapter68.pdf>.

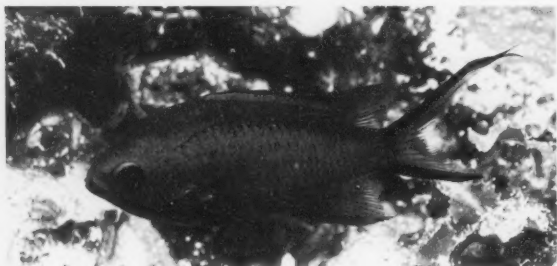
<sup>14</sup> FMRI. 2000. Marine fisheries trip ticket program data. Unpublished data obtained from the Florida Marine Fisheries Institute, Florida Fish and Wildlife Conserv. Comm., 100 Eighth Avenue S.E., St. Petersburg, FL 33701-5095.



Yellowhead jawfish,  
*Opistognathus aurifrons*.  
Photo by Dr. Luiz A. Rocha,  
Smithsonian Tropical Research Unit.



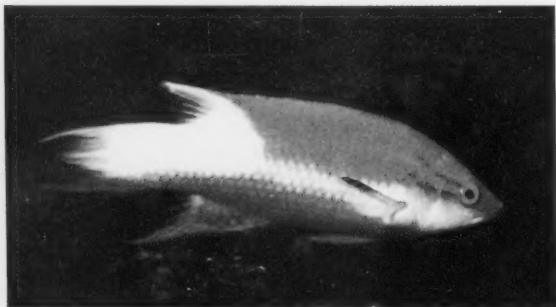
Blue angelfish,  
*Holacanthus bermudensis*.  
Photo by Dr. Luiz A. Rocha,  
Smithsonian Tropical Research Unit.



Blue chromis,  
*Chromis cyanea*.  
Photo by Dr. Luiz A. Rocha,  
Smithsonian Tropical Research Unit.



Bluehead wrasse,  
*Thalassoma bifasciatum*.  
Photo by Dr. Luiz A. Rocha,  
Smithsonian Tropical Research Unit.



Spotfin hogfish,  
*Bodianus pulchellus*.  
Photo by Dr. Luiz A. Rocha,  
Smithsonian Tropical Research Unit.

Table 1.—Number of commercial participants in the Florida marine life industry (FMRI, text footnote 14).

License year	Active <sup>1</sup> wholesale dealers	Restricted species endorsements	Saltwater products license		Marine life endorsements	
			Total	Active	Total	Active
1990–91	69	127	349	297	159	107
1991–92	91	265	436	289	311	164
1992–93	109	362	521	329	389	197
1993–94	114	431	572	317	477	222
1994–95	112	523	655	318	566	229
1995–96	103	589	698	273	630	205
1996–97	98	626	706	213	668	175
1997–98	105	726	844	241	801	198
1998–99	66	703	767	152	743	128

<sup>1</sup> The term active refers to license numbers that reported landings during the year.

reported landings), however, has remained fewer than 230. Only 128 MLE's were active in 1998. The total number of MLE's issued declined recently due to a moratorium established 1 July 1998 that will remain in effect at least until 1 July 2005. However, there continues to remain a significant amount of latent

effort in the fishery (33% in 1990 and 83% in 1998).

### Product Types

A total of 318 marine ornamental species were landed in Florida for commercial purposes from 1990 to 1998. The total includes 181 species of fish (57%) and 137 invertebrate species (43%), which includes live rock, live sand, and various plant species. Slightly over 70% of fish species (121) and about half of the invertebrate species (71) are classified as "restricted" (i.e. requiring an additional license to harvest).

Aside from the type of organism and restricted status, each specimen is identified by its common name, genus, species, and/or family by FMRI. For the fishes, species that share a common

name typically are from the same family. For example, there are nine species of parrotfish that are all members of the Scaridae family. Of the 181 fish species landed, there are a total of 67 common names representing 51 families (e.g. bass, groupers, hamlets, and perch are all members of the Serranidae family). The common fish and invertebrate names for live marine specimens harvested for commercial use in Florida are listed in Table 2.

For the invertebrate species, common names do not match specific families as closely as the fish species. For example, the 26 "snails" represent 21 different families and the 15 "crabs" represent 10 families. When grouped by common name, however, the 137 species are reduced to 32 common-name groups. In this analysis, live rock and live sand are frequently distinguished from the remaining invertebrates, which are not further divided.

Table 3 lists the 10 species groups of fish and invertebrates that accounted for the highest average annual landed values, which were calculated from reported landings and prices received by harvesters (i.e. harvester revenues), and the primary species within each group in terms of landed value. The jawfish and butterflyfish groups are

Table 2.—Common names of marine ornamental species collected in Florida, 1990–98 (FMRI, text footnote 14).

Fish	Invertebrates
Angelfish (6)	Moray (5)
Balloonfish	Parrotfish (9)
Barracuda	Perch
Bass (6)	Pilotfish
Batfish	Pipefish
Bigeye	Porgy
Blenny (8)	Puffer (3)
Brotula	Ray (4)
Burrfish	Razorfish
Butterflyfish (6)	Remora (2)
Cardinalfish (3)	Scorpionfish (2)
Catfish	Seahorse (3)
Chub	Searobin
Clingfish	Shark (3)
Coronatefish (3)	Sheephead
Cowfish (3)	Skate
Cusk-eel	Snapper (3)
Damselfish (14)	Soapfish
Drum (4)	Soldierfish
Filefish (6)	Spadefish
Flounder	Squirrelfish (3)
Frogfish (2)	Stargazer (2)
Goatfish (2)	Stingray (2)
Goby (3)	Surgeonfish
Grouper (5)	Sweeper
Grun (5)	Tang (3)
Hamlet (6)	Tilfish
Hawkfish	Toadfish
Hogfish (3)	Triggerfish (3)
Jack (2)	Tripletail
Jawfish (4)	Trumpetfish
Lizardfish	Trunkfish (2)
Minnow	Wrasse (8)
Mojarra	

Note: Names reflect the biological family and the numbers in parentheses correspond to the number of different genus and species combinations related to the family. Names are listed in alphabetical order.

Table 3.—Top 10<sup>1</sup> marine fish and invertebrate species in terms of average value, 1990–98 (FMRI, text footnote 14).

Common name	Species	Scientific name	Percent value by name
Fish			
1. Angelfish	Blue	<i>Holocanthus bermudensis</i>	26%
2. Hogfish	Spotfin (Cuban)	<i>Bodianus pulcheilus</i>	70
3. Damselfish	Blue chromis (reef)	<i>Chromis cyanea</i>	37
4. Jawfish	Yellowhead	<i>Opistognathus aurifrons</i>	91
5. Wrasse	Bluehead	<i>Thalassoma bifasciatum</i>	54
6. Butterflyfish	Spotfin	<i>Chaetodon ocellatus</i>	99
7. Seahorse	Dwarf	<i>Hippocampus zosterae</i>	76
8. Parrotfish	Striped (painted)	<i>Scarus croicensis</i>	57
9. Surgeonfish	Blue	<i>Acanthurus coeruleus</i>	82
10. Drum	High-hat	<i>Equetus acuminatus</i>	57
Invertebrates			
1. Live rock	Algae	N/A <sup>2</sup>	36
2. Snail	Turbonella	Family Turbellidae	45
3. Anemone	Giant Caribbean	<i>Condylactis gigantea</i>	63
4. Crab	Horseshoe	<i>Limulus polyphemus</i>	33
5. Starfish	Red spiny sea star	<i>Echinaster sentus</i>	65
6. Gorgonian	Red	<i>Swiftia exserta</i>	38
7. Sand dollar	Other	<i>Encope, Leofia, Mellita</i> spp.	90
8. Sea urchin	Variable or green	<i>Lytechinus variegatus</i>	56
9. Sponge	Red tree	Class Demospongia	51
10. Live sand	N/A	N/A	NA

<sup>1</sup> Rankings are based on average value of landings to harvesters, 1990–98. Top individual species (by economic value) based on 1990–96 landings data.

<sup>2</sup> N/A indicates not applicable.

comprised primarily (91–99%, respectively) of a single species, namely, the yellowhead, *Opistognathus aurifrons*, and spotfin, *Chaetodon ocellatus*, respectively. Among the invertebrates, no single species comprises more than 65% of the total value of any of the top 10 groups.

### Regional Data

The State of Florida has defined 17 primary marine fishing areas for the purpose of data collection. Finer geographic resolution is available within each of the primary areas as Federal waters are distinguished and state waters are divided

into smaller subareas. Trip tickets with area information represented about 75% of the total number of trips reported and 77% of the total value (as received by the harvester) of marine life landed. The source region was not reported for 16% of trips that accounted for 15% of landed value.

Only 8 of the 17 primary areas were reported as significant sources of marine life collected for commercial purposes. The identified collecting regions ranged from the Crystal River to Tarpon Springs areas on Florida's west coast down to the Miami area on Florida's southern east coast. Overall, the Marathon area accounted for the highest value of landings (31% or \$7.2 million) and the highest number of trips (39% or nearly 181,000).

### Seasonal Data

To examine seasonal differences, the total landed value of fish and invertebrates was calculated for each quarter (January–March, April–June, July–September, October–December). In general, fish landings have been somewhat equally distributed during the season in terms of value to the harvester. When fish revenues were highest, in 1994, the second quarter accounted for a relatively larger share. On average, the value of fish landings were highest during the second quarter and lowest during the fourth quarter; average fish landings were valued at \$274,387 and \$208,958 (accounting for 28% and 22% of average annual landings) for the second and fourth quarters, respectively.

When the revenues are examined for the top 10 revenue-generating groups of fish species, some seasonal patterns are evident. Figure 1 (top panel) shows the quarterly revenue shares for each of the top fish species. For the top 2 fish species, revenues are roughly equally distributed throughout the year. Jawfish and drum are primarily caught in the third quarter and each contribute relatively little in the first quarter. Conversely, the value of parrotfish and surgeonfish landings have been highest in the first quarter. Seahorses are the only species group for which the share of annual landings value falls below 20% in the fourth quarter.

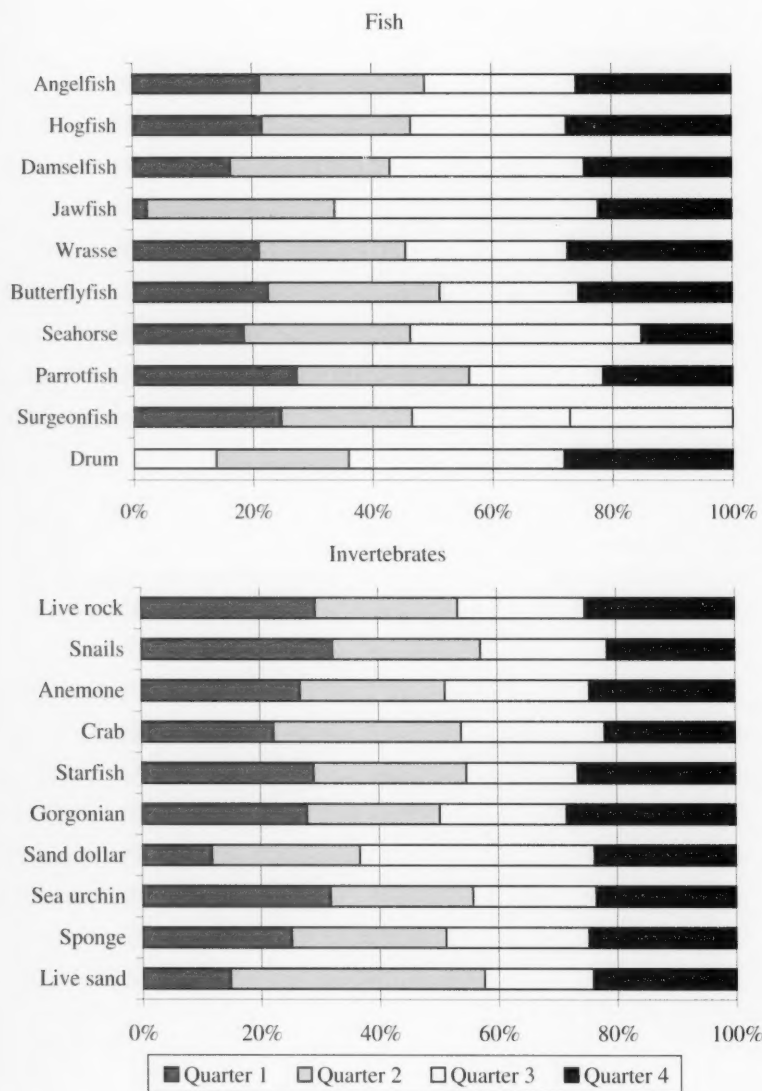


Figure 1.—Quarterly revenues for the top 10 marine fish and invertebrate species groups, 1990-98 (FMRI, text footnote 14).

The quarterly total value of invertebrates ranged from \$404,072 (accounting for 24%) to \$456,746 (accounting for 26%) for the first and third quarters, respectively (Figure 1, bottom panel). There was no noticeable change in landings distribution over time and, thus, this information was not included.

When comparing the fish revenue distribution with the invertebrates, the first quarter accounted for a larger share of annual revenues for the invertebrate species. Sand dollars and live sand were the exception, where revenues of these species were highest in the second and third quarters, as with the majority of fish species. Over 40% of live sand revenues were reported from April through June. The share of revenues (landed values) in the fourth quarter was above 20% for all invertebrate species and all fish species except seahorses. With the exception of sand dollars, it appears that invertebrate revenues are lowest in the summer months (July through August).

#### Data by Product Type

Annual landings for fish averaged 295,060 individuals over the 1990–98 period. Landings for invertebrates as a group cannot be summed due to differences in measurement units across species. For example, live rock is measured in pounds and anemones are measured by number. In terms of annual value, fish and invertebrates averaged \$1,006,822 and \$1,730,059, respectively. Thus, invertebrates are worth more to the industry since they collectively averaged 63% of total industry value over the study period. The average invertebrate share was, however, affected by the surge in the collection of wild live rock that peaked in 1995 when invertebrate species accounted for 73% of total industry value. The invertebrate share was lowest in 1990 at 45%, prior to the establishment of the live rock and live sand collection activities.

The total value (harvester revenues) of Florida marine life landings increased from \$1.4 million in 1990 to about \$4.3 million in 1994. The total value of this fishery then decreased to about \$1.9 million by 1998. The decline is explained by a reduction in live rock and live sand landings, which fell from about 1.2 mil-

Table 4.—Annual commercial landings and value of marine fish and invertebrates collected in Florida by type, 1990–98 (FMRI, text footnote 14).

Year	Fish		Animals		Plants		Live rock and live sand	
	No.	Value	No.	Value	Gal.	Value	Lb.	Value
	(1,000)	(\$1,000)	(1,000)	(\$1,000)	(1,000)	(\$1,000)	(1,000)	(\$1,000)
1990	245	767	849	377	31	0	249	252
1991	291	987	893	467	30	38	581	853
1992	393	971	1,352	581	28	48	777	1,433
1993	355	1,284	1,989	1,036	35	33	954	1,213
1994	426	1,613	1,888	1,209	31	29	1,092	1,422
1995	259	944	2,171	1,053	37	43	1,180	1,432
1996	206	833	2,637	899	20	31	809	843
1997	278	904	3,148	911	21	41	185	183
1998	201	759	3,340	897	14	22	167	218

lion pounds in 1995 to 167,000 pounds in 1998 (Table 4). The reason for the dramatic decrease was the prohibition of all commercial harvest of live rock and sand, in both Atlantic Ocean and Gulf of Mexico waters adjacent to Florida. The only exception is the harvest of live rock from permitted commercial culture sites approved by the appropriate state or Federal agencies. By 1998, there were seven commercial live rock culture leases off the coast of Florida, but total production has remained low (FMRI<sup>14</sup>).

#### Fish Species Data

Landings and value of marine ornamental finfish increased to peak levels in 1994, then decreased through 1998. Reported landings increased from 245,000 individual fish in 1990 to 426,000 in 1994, then declined to about 200,000 in 1998 (Table 4). Total value followed the same general pattern, increasing from \$767,000 in 1990 to \$1.6 million in 1994, then declining to \$759,000 in 1998. In 1992, landings increased 35% while the total value of landings declined slightly. The increased landings were due specifically to a five-fold increase in the collection of seahorses (from about 14,000 harvested in 1991 to 83,700 harvested in 1992), primarily *Hippocampus zosterae* (i.e. dwarf seahorses). In addition, the increased landings of seahorses lowered market prices; the average price paid by dealers for seahorses fell from \$1.10 in 1991 to \$0.17 in 1992, a decline of nearly 84%.

During the 1990–98 period, 181 individual species of finfish were harvested. For simplicity, these species were

grouped into 67 categories using their common name as defined by FMRI; a three-digit code for each species is associated with a (1) common name, 2) genus and species, and 3) family. The common name is most closely associated with the family. For example, the data set contains three genus and species of "cowfish" including *Lactophrys polygonia*, *L. quadricornis*, and family Ostraciidae, which are listed (in common name field), respectively, as honeycomb cowfish, scrawled cowfish, and other cowfish. Although each species has its own unique code, each is a member of the Ostraciidae family, and data from all three are aggregated and included under the common name "cowfish." Note that not all codes are associated with a unique genus and species and, thus, fall into an "other" category. Consequently, the number of individual species should be considered as conservative.

The 67 aggregate finfish groups are listed in Table 2. If a group consists of multiple species, parentheses are used to indicate the number of individual species that are included in the common name groupings. Of these groups, ten accounted for nearly 84% of the total value. The most important species group was angelfish, which represented 54% of the total value. Hogfish accounted for 7.5% of the total while the other eight groups accounted for about 22% of the total value of live marine finfish collected from 1990 to 1998. Since each species group contains multiple species, it may be helpful to know how important any single species may be, especially when regulations can be enacted at the species level.

Table 5.—Annual commercial landings of the top 10 marine fish species by common name that account for the highest average landed value, 1990–98, in Florida (FMRI, text footnote 14).

Common name	Number of specimens landed annually									Average
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
1. Angelfish	71,459	82,589	86,711	79,782	82,668	73,666	60,602	59,817	48,839	71,793
2. Hogfish	8,535	8,794	9,888	10,112	13,494	12,451	10,633	7,869	7,419	9,911
3. Damselfish	32,150	31,702	38,337	21,558	29,387	27,504	14,102	21,703	21,225	26,408
4. Jawfish	6,325	4,995	16,624	22,151	28,267	13,596	9,285	8,976	5,894	12,901
5. Wrasse	23,440	25,032	27,227	20,686	21,713	16,920	12,453	16,633	13,512	19,735
6. Butterflyfish	12,667	15,266	15,479	13,213	12,949	9,420	6,941	6,772	6,551	11,029
7. Seahorse	5,969	13,982	83,715	71,815	110,948	23,341	19,037	90,049	16,977	48,426
8. Parrotfish	4,953	5,760	8,374	6,212	8,728	3,876	2,866	4,004	2,998	5,308
9. Surgeonfish	6,511	6,881	8,930	9,342	8,378	6,791	5,359	5,961	7,702	7,317
10. Drum	11,891	9,816	9,505	10,569	11,526	9,086	7,233	6,661	6,781	9,230

Table 6.—Annual average unit price of the top 10 marine fish species by common name that account for the highest average landed value, 1990–98, in Florida (FMRI, text footnote 14).

Common name	Average unit price (\$ each)									Average
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
1. Angelfish	\$5.62	\$7.00	\$6.61	\$9.13	\$8.85	\$6.92	\$7.61	\$8.54	\$8.12	\$7.60
2. Hogfish	7.43	6.56	4.01	8.84	9.23	7.28	7.89	8.23	8.44	7.55
3. Damselfish	1.33	1.20	1.08	1.53	2.01	1.30	1.22	1.12	1.19	1.33
4. Jawfish	2.01	2.19	2.17	2.38	3.07	2.44	2.60	2.58	2.36	2.42
5. Wrasse	1.48	1.65	1.20	1.44	2.40	1.60	1.70	1.65	1.68	1.64
6. Butterflyfish	2.65	2.74	2.10	2.78	4.14	2.20	2.59	3.17	2.35	2.86
7. Seahorse	1.13	1.10	0.17	0.12	0.88	1.07	1.34	0.35	0.80	0.77
8. Parrotfish	2.90	4.29	3.33	6.72	6.40	4.04	5.21	5.18	5.74	4.87
9. Surgeonfish	3.34	2.44	1.85	3.34	4.05	2.51	3.41	3.41	3.47	3.06
10. Drum	1.83	1.81	1.48	2.02	3.46	1.77	2.24	2.24	2.11	2.17

With the exception of seahorses and surgeonfish, all top fish species groups exhibited a decline in landings volumes from 1990 to 1998 (Table 5). The largest species group decline was reported to be the butterflyfish (–48%), while seahorses were the species group with the largest increase (184%).

Average per unit prices varied considerably across species. For example, in 1998 the average unit price for angelfish and hogfish both exceeded \$8 per fish, while the unit price for damselfish, jawfish, wrasse, butterflyfish, and drum were less than \$3 (Table 6). The average price for seahorses was less than \$1. With the exception of angelfish, the species exhibiting the highest landings volume (i.e. damselfish, wrasse, and seahorses) also showed the lowest average unit price. The average unit price for angelfish varied considerably during the 1990–98 period, increasing from \$5.62 in 1990 to \$9.13 in 1993, before declining to \$6.92 in 1995. The unit average price for angelfish then increased to \$8.12 in 1998.

#### Invertebrate Species Data

The 137 individual species of invertebrates collected by the marine life industry in Florida from 1990 to 1998 were analyzed by their 32 respective common names (Table 2). Due to the diversity of the invertebrate species, these groups are further aggregated into the following three categories: 1) invertebrate animals (including crustaceans, mollusks, starfish, anemones, sea cucumbers, sponges, nudibranchs, bryozoa, etc.), 2) plants (including those of the Caulerpaceae, Halimedaceae, and Corallinaceae families), and 3) live rock and live sand.

The patterns in invertebrate landings volumes and value during the 1990 to 1998 period varied somewhat across the three major groups. Landings of invertebrate animals exhibited an increase from about 850,000 individual animals in 1990 to over 3.3 million in 1998, an increase of 290% (Table 4). However, the total value of the animals increased from about \$376,000 in 1990 to a peak of \$1.2

million in 1994, then declined steadily to \$896,000 in 1998 as less valuable species on a per unit basis (such as snails, starfish, and sand dollars) garnered an increasing share of total landings by volume.

Landings of marine plants increased from about 31,000 gallons in 1990 to a peak of 37,000 gallons in 1995. Plant landings then declined dramatically (about 62%) to 14,000 in 1998 (Table 4). The value of marine plants reached peaks in 1992 and 1995, then declined with landings volumes to \$22,000 in 1998.

The landings of live rock and live sand mirror the enactment of legislation intended to eliminate the harvest of naturally occurring live rock. Live rock landings increased from 249,093 pounds in 1990 to about 1.1 million pounds in 1995, a 340% increase (Table 7). Following the moratorium on landings in Federal waters, landings decreased to 90,975 pounds in 1998. The value of live rock and sand reached equivalent peaks of about \$1.4 million in 1992 and 1995, then decreased dramatically to a total of

Table 7.—Annual commercial landings of the top 10 marine invertebrate species by common name that account for the highest average landed value, 1990–98, in Florida (FMRI, text footnote 14).

Common name	Landings (no. or lb.)									Average
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
1. Live rock <sup>1</sup>	249,093	581,376	776,810	954,197	1,087,065	1,094,723	671,226	104,044	90,975	623,279
2. Snail <sup>2</sup>	90,369	182,180	257,752	293,688	288,406	480,706	470,357	493,614	805,210	373,587
3. Anemone <sup>2</sup>	272,476	302,701	334,043	293,590	307,891	335,795	233,649	200,533	201,629	275,812
4. Crab <sup>2</sup>	92,250	90,845	119,591	152,375	117,889	181,074	252,882	334,559	788,598	236,674
5. Starfish <sup>2</sup>	26,575	28,220	129,574	333,911	314,071	222,102	543,782	975,368	511,297	205,012
6. Gorgonian <sup>2</sup>	17,803	24,350	23,898	29,960	32,106	35,976	37,057	44,867	40,743	28,736
7. Sand dollar <sup>2</sup>	254,832	88,191	193,574	560,480	578,574	619,716	776,582	781,567	771,817	438,850
8. Sea urchin <sup>2</sup>	31,745	35,495	33,008	41,156	39,052	41,268	36,039	33,232	40,900	36,823
9. Sponge <sup>2</sup>	17,017	18,858	17,886	18,626	18,236	17,659	14,459	15,464	17,166	17,534
10. Live sand <sup>1</sup>	N/A <sup>3</sup>	N/A	N/A	N/A	4,802	86,175	138,194	81,129	75,584	42,876

<sup>1</sup> Pounds landed (lb.).

<sup>2</sup> Number landed (no.).

<sup>3</sup> Not applicable (N/A).

Table 8.—Annual unit price of the top 10 marine invertebrate species by common name that account for the highest average landed value, 1990–98, in Florida (FMRI, text footnote 14).

Common name	Average unit price (\$)									Average
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
1. Live rock <sup>1</sup>	\$1.01	\$1.47	\$1.84	\$1.27	\$1.30	\$1.20	\$1.12	\$1.30	\$1.93	\$1.38
2. Snail <sup>2</sup>	0.38	0.22	0.37	0.61	0.55	0.68	0.28	0.26	0.21	0.40
3. Anemone <sup>2</sup>	0.37	1.47	0.42	0.48	0.53	0.43	0.44	0.47	0.48	0.57
4. Crab <sup>2</sup>	0.48	0.43	0.40	1.46	0.86	0.55	0.42	0.34	0.18	0.57
5. Starfish <sup>2</sup>	0.80	0.78	0.12	0.30	0.95	0.23	0.17	0.08	0.09	0.39
6. Gorgonian <sup>2</sup>	1.98	1.58	0.94	2.23	3.80	2.42	2.80	2.47	2.41	2.29
7. Sand dollar <sup>2</sup>	0.12	0.27	0.15	0.17	0.12	0.10	0.11	0.11	0.08	0.14
8. Sea urchin <sup>2</sup>	0.50	0.56	0.34	0.55	1.12	1.77	1.86	1.94	1.67	1.14
9. Sponge <sup>2</sup>	1.59	1.76	1.49	1.93	3.22	2.77	3.05	2.96	2.87	2.40
10. Live sand <sup>1</sup>	N/A <sup>3</sup>	N/A	N/A	1.00	0.78	1.39	0.68	0.59	0.56	0.83

<sup>1</sup> Dollars per pound landed (\$/lb.).

<sup>2</sup> Dollars per specimen landed (\$ each).

<sup>3</sup> Not applicable (N/A).

\$218,000 in 1998 (Table 4) as reported landings consisted only of live rock cultured on permitted lease sites.

Ten invertebrate species groups accounted for over 89% of the total value attributable to invertebrate animals, plants, and live rock and sand during the 1990–98 period. The most important single species group was live rock, which accounted for almost 50% of the value accumulated during the 1990–98 period, despite the drastic declines following the 1995 moratorium. Snails, anemones, and crabs combined accounted for 20% of the value, with the other six species contributing the remaining 30% of the total value.

With the exception of live rock and anemones, all of the top 10 invertebrate species groups experienced net increases in landings volumes during the 1990–98

period, with some being dramatic. For example, starfish, snails, and crabs, exhibited increases in landings of 1,824%, 791%, and 755%, respectively, from 1990 to 1998 (Table 7). As with finfish species, prices also varied across invertebrate species groups (Table 8). The highest average unit prices during the 1990 to 1998 period were associated with sponges (\$2.40), gorgonians (\$2.29), live rock (\$1.38 per pound), and sea urchins (\$1.14).

#### Trip-level Data

Data were provided on an individual species basis, thus, trip information (i.e. number of trips) was averaged by species, then averaged by species group. Hence, the aggregate number of trips cannot be determined; this information would need to be evaluated at the collector level. Due

to confidentiality, however, this information is not sufficiently complete for purposes of analysis. This is because several full-time collectors essentially specialize in the harvest of certain species. These individuals land other species but have developed either special skills needed to collect certain species (especially fish) or have found areas where such species are located (Larkin and Degner, 2001). In addition, some collectors even cultivate certain resources, leaving juveniles to harvest at a later date when they are larger and can command a higher price.

From 1990 to 1998, landings of fish per trip for a given species averaged 9.3 but were reported to be as much as 7,800 while landings of invertebrates per trip for a given species averaged 158 but were reported to be as much as 92,500 (FMRI<sup>14</sup>). This extreme variation reflects

Table 9.—Annual landings per trip of the top 10 marine fish species by common name that account for the highest average landed value, 1990–98, in Florida (FMRI, text footnote 14).

Common name	Average landings per trip (no.)									Average
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
1. Angelfish	9.2	8.2	9.4	9.3	8.1	9.7	9.6	7.5	6.9	8.7
2. Hogfish	5.1	3.9	4.4	4.4	6.3	6.8	6.7	5.2	6.4	5.5
3. Damselfish	14.3	9.6	9.8	6.7	9.7	12.7	10.7	10.0	12.7	10.7
4. Jawfish	10.7	8.6	18.1	17.4	21.4	16.1	14.4	29.8	27.4	18.2
5. Wrasse	8.8	7.3	6.8	5.6	7.6	7.5	6.8	9.6	10.1	7.8
6. Butterflyfish	3.5	3.5	4.1	3.8	3.3	3.8	3.6	3.8	4.0	3.7
7. Seahorse	26.0	54.7	148.0	139.7	447.4	381.9	193.1	15.3	50.9	161.9
8. Parrotfish	3.5	3.4	3.7	3.1	4.0	3.8	2.8	4.8	4.0	3.7
9. Surgeonfish	3.6	3.5	3.7	3.8	3.3	4.2	4.1	5.8	6.9	4.3
10. Drum	10.3	7.8	6.3	6.3	7.6	7.4	7.5	9.4	8.8	7.9

Table 10.—Annual landings per trip of the top 10 marine invertebrate species by common name that account for the highest average landed value, 1990–98, in Florida (FMRI, text footnote 14).

Common name	Average landings per trip (no. or lb.)									Average
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
1. Live rock <sup>1</sup>	181.3	237.4	232.1	274.5	280.3	364.0	417.3	404.1	571.4	329.1
2. Snail <sup>2</sup>	96.8	109.0	150.9	154.8	162.9	365.7	391.3	382.4	416.7	247.8
3. Anemone <sup>2</sup>	167.8	133.4	131.5	109.0	148.0	182.0	134.9	177.8	182.5	151.9
4. Crab <sup>2</sup>	33.4	25.5	28.3	72.6	29.7	49.9	129.0	106.9	225.8	77.9
5. Starfish <sup>2</sup>	N/A <sup>3</sup>	N/A	N/A	N/A	N/A	N/A	N/A	21.0	19.5	20.1
6. Gorgonian <sup>2</sup>	24.4	17.8	17.5	21.2	23.8	24.3	20.6	53.6	40.3	27.0
7. Sand dollar <sup>2</sup>	14,459.5	2,320.8	2,901.5	3,517.5	5,524.8	6,272.7	6,359.4	7,414.0	14,352.0	7,013.6
8. Sea urchin <sup>2</sup>	25.1	31.1	25.3	29.3	29.2	30.1	25.0	37.3	41.0	30.4
9. Sponge <sup>2</sup>	12.0	13.5	10.3	13.2	13.5	12.8	11.5	12.7	16.9	12.9
10. Live sand <sup>1</sup>	N/A	N/A	N/A	N/A	358.0	501.2	1,896.5	1,223.6	N/A	994.8

<sup>1</sup> Pounds landed (lb.).

<sup>2</sup> Number landed (no.).

<sup>3</sup> Not applicable (N/A).

Table 11.—Annual revenue per trip of the top 10 marine fish species by common name that account for the highest average landed value, 1990–98, in Florida (FMRI, text footnote 14).

Common name	Average revenue per trip (\$)									Average
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
1. Angelfish	49.29	55.42	60.25	78.09	67.03	64.44	75.52	66.13	58.93	63.90
2. Hogfish	35.37	25.36	17.80	37.92	57.60	48.80	52.36	42.28	55.28	41.42
3. Damselfish	21.22	12.18	11.17	10.08	19.94	16.65	13.09	11.65	15.89	14.65
4. Jawfish	21.97	17.73	39.09	41.71	68.23	40.28	37.49	77.57	65.18	45.47
5. Wrasse	15.70	12.62	8.01	8.57	20.19	11.46	13.01	16.90	16.25	13.63
6. Butterflyfish	9.08	15.01	22.19	12.88	17.73	8.96	12.64	9.96	8.89	13.04
7. Seahorse	21.37	47.31	20.92	21.02	596.51	366.56	205.44	26.96	55.56	151.29
8. Parrotfish	14.97	13.69	15.38	26.53	28.99	17.20	20.85	24.97	21.07	20.41
9. Surgeonfish	10.15	9.38	9.56	14.47	12.56	11.18	13.01	19.72	33.23	14.81
10. Drum	31.94	22.33	15.71	18.39	36.00	15.64	19.94	21.40	14.90	21.81

the ability of collectors to harvest thousands of small "critters" in a very short period of time. Because the data do not allow for the evaluation of all species landed on each trip, these trip-level data may be conservative estimates of the activity of collectors that harvest multiple species during a given trip.

Aside from the aggregate averages, it is helpful to examine the data for the individual species. To that end, infor-

mation on annual average landings and value (i.e. total harvest revenue) are calculated at the trip level for each of the top 10 fish and invertebrate species groups (Tables 9–12).

With the exception of seahorses, landings for fish species within the top 10 groups averaged between 4 and 18 fish per trip (seahorse landings averaged 162 per trip) (Table 9). Jawfish is perhaps the only species group whose landings per

trip have increased over time; the average catch rate per trip increased from nearly 11 fish per trip in 1990 to over 27 per trip in 1998. In general, landings of each species varied annually.

Landings per trip (i.e. catch rate) for the top invertebrate species are summarized in Table 10. In general, catch rates for invertebrates greatly exceed those for fish. Only 4 of the top 10 invertebrate species were characterized

Table 12.—Annual revenue per trip of the top 10 marine invertebrate species by common name that account for the highest average landed value, 1990–98, in Florida (FMRI, text footnote 14).

Common name	Average revenue per trip (\$)									Average
	1990	1991	1992	1993	1994	1995	1996	1997	1998	
1. Live rock	185.85	327.09	400.78	340.76	408.55	417.32	460.52	728.67	1,001.15	474.52
2. Snail	54.93	28.69	55.48	87.37	102.61	511.41	112.48	111.85	102.07	129.65
3. Anemone	74.89	79.78	66.04	68.92	91.25	85.05	70.08	92.49	93.90	80.27
4. Crab	16.55	11.42	14.54	158.54	26.46	28.90	45.59	49.40	47.10	44.28
5. Starfish	N/A <sup>1</sup>	N/A	N/A	N/A	N/A	N/A	N/A	17.87	16.24	17.06
6. Gorgonian	52.68	24.75	16.64	47.96	99.22	53.31	67.11	134.55	96.26	65.83
7. Sand dollar	1,753.09	623.22	448.83	871.36	675.04	687.00	637.74	748.00	1,046.00	832.25
8. Sea urchin	13.74	20.54	12.13	17.51	32.37	39.23	25.59	40.89	37.57	26.62
9. Sponge	19.76	22.57	16.68	28.68	25.19	30.48	25.75	31.77	47.54	27.60
10. Live sand	N/A	N/A	N/A	N/A	395.58	822.11	971.33	448.38	N/A	659.35

<sup>1</sup> Not applicable (N/A).

by landings of equal to or less than 30 specimens per trip. Landings of sand dollars averaged 7,014 per trip, which is significantly higher than that for the next highest group, snails, with 248 per trip. Note that live rock and live sand are both measured in pounds and thus cannot be compared to other invertebrate species. However, trends in average catch rates are comparable. Most of the top invertebrates experienced increases in catch rates between 1990 and 1998. In particular, landings of live rock, snails, anemones, and crabs all increased.

The average annual revenue received per trip by fish species group is shown in Table 11. Recall that since collectors can harvest multiple species during a given trip, these revenues may not equal the total trip revenue. Average revenues for the top fish species ranged from about \$13 to \$151 for butterflyfish and seahorses, respectively. With the exception of seahorses, the next highest revenue generator per trip was angelfish, which accounted for about \$64 per trip. When comparing the average landings in the first few years vs. the last, it appears that revenues per trip for hogfish, jawfish, and surgeonfish have increased while those for damselfish, butterflyfish, and drum have declined slightly.

The average revenue per trip for invertebrates exceeded that for fish (Table 12). Among the top 10 invertebrate species, trip revenues averaged from about \$17 for starfish to over \$800 for sand dollars. It may be that effort directed at invertebrates is more specialized and thus fewer different species are landed per trip. During the 1990–98

period, revenues per trip increased for nearly all species, especially live rock. However, note that live rock landings are no longer unrestricted since all production must come from permitted culture lease sites.

### Summary and Conclusions

The marine life collection industry in Florida has grown during the past decade as the number of licensed collectors (i.e. fishermen with MLE's) increased from 159 to 743. As a result, the volume and/or value of landings of the top 10 fish and invertebrate species groups increased. The growth is particularly evident in the collection of invertebrate animals (i.e. excluding plants, live rock, and live sand). The harvest of live rock and live sand also increased dramatically during the 1990–95 period, but declined due to a moratorium on the collection of naturally occurring rock and sand in state and Federal waters.

Although the number of harvesting participants increased dramatically during the 1990–98 period, the implementation of a temporary moratorium on marine life endorsements has limited further entry into the industry until 2005. Regulations have also been imposed on certain species (e.g. size limits, bag limits, and trip limits), but most regulations apply to the industry as a whole (e.g. allowable harvest methods). The implementation of these regulations reflects concern regarding the sustainability of marine life resources in Florida.

The information presented in this paper includes data collected by FMRI since the initiation of the marine life

trip ticket program in 1990. The reported regional, seasonal, and trip-level analysis (along with trends in landings, prices, and/or total values) provides some insight into the harvest pressure being exerted on wild stocks of ornamental finfish and invertebrate animals. Although no stock assessments exist for any of the individual species targeted by the marine life collection industry, such information (particularly for the predominant species) could be useful to resource managers as they develop effective management measures for this growing industry.

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# Elasmobranch Landings for the Portuguese Commercial Fishery From 1986 to 2001

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## Introduction

Fishing has been important to the livelihood of the Portuguese for centuries. Some coastal communities are almost totally dependent on fishing or related activities (DGPA, 1998). The nation's fishing grounds are delineated by an EEZ (Exclusive Economic Zone) of 1,700,000 km<sup>2</sup>, encompassing both continental Portugal (with a coastline of 942 km) and two large insular regions surrounding the Azores and Madeira (DGPA, 1998).

Historically, fisheries have targeted elasmobranchs to supply the liver-oil or "squalene" market (Holts, 1988; Last

and Stevens, 1994). Elasmobranchs have also been landed, and in many cases discarded, as the bycatch of other fisheries (Berkeley and Campos, 1988; Stevens, 1992). More recently, however, elasmobranchs have been targeted specifically to provide a source of protein in the form of meat and fins (Cailliet and Bedford, 1983; Holts, 1988).

The life history of elasmobranchs is characterized by slow growth rates, late maturity, long gestation periods, and the production of a small number of offspring (Holden, 1973; Pratt and Casey, 1990). These characteristics are customarily coupled with a distinctive predatory behavior (Gruber, 1982). Elasmobranchs therefore frequently represent an important "apex" role within their respective food web, and the depletion of their stocks could potentially cause a rapid and profound negative impact upon the ecosystem from which they are drawn (Gruber, 1982).

In addition, the nature of their life history frequently subjects elasmobranchs to a "high risk" of overfishing (Holden, 1973, 1974, 1977). Many publications highlight the inability of elasmobranchs to sustain strong fishing pressure for any extended period, as overfishing often translates into a rapid decline of population numbers (Pratt and Casey, 1990; Pepperell, 1992; Stevens, 1992; Musick et al., 1993; Sminkey and Musick, 1995). The delicate nature of elasmobranch populations emphasizes the need for effective conservation and management measures for this important taxonomic group.

In 1983, the Portuguese elasmobranch fishery expanded rapidly due to an increasing demand for shark by-products

(i.e. oil, liver, etc.) and as the bycatch of an accelerated deep-sea teleost fishery (Nunes et al.<sup>1</sup>). In 1985, the demand for shark by-products peaked (oil prices reached US\$4.00 ~ US\$5.00 per liter) and then declined from 1987 to 1999 (oil prices decreasing to less than US\$1.00 per liter) (Nunes et al.<sup>1</sup>). During the same period, the demand for elasmobranch flesh steadily increased, and at present, this represents the principal elasmobranch product marketed in Portugal. The flesh of these fishes is sold for human consumption either directly (in the case of many species of Rajidae and Squalidae) or indirectly (i.e. processed into other food products) (Nunes et al.<sup>1</sup>).

Portugal's elasmobranch fishery is not regulated, and thus there are no established size or catch quota limits. The "fishery" consists mainly of: 1) targeted deep-sea elasmobranch longlining; 2) targeted pelagic elasmobranch surface longlining; 3) bycatch of deep-sea elasmobranchs from black scabbardfish, *Aphanopus carbo*, longlining; 4) bycatch of pelagic elasmobranchs from teleost gill-netting, purse seining, and bottom trawling; and 5) bycatch of skates and rays from crustacean bottom trawling.

Despite their species' high-risk nature, elasmobranch fisheries have been little studied in this region. In Portugal, what little work has been published consists mainly of internal reports, most of which came from the Portuguese Marine Research Institute (Instituto de Investigação das Pescas e do Mar, IPIMAR)

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**ABSTRACT**—Portuguese commercial elasmobranch landings were analyzed for the period 1986–2001. An average of 5,169 ( $\pm 795$  t) were landed yearly, representing 18 families, 29 genera, and 34 confirmed species. However, annual landings for the fishery generally decreased over time, with a corresponding increase in price per kilogram. The most important group, *Raja* spp., accounted for 33% of the landings or 26,916 t. They were followed by *Centroscymnus coelolepis*, *Scyliorhinus* spp., *Centrophorus granulosus*, and *Centrophorus squamosus* (accounting for 12%, 12%, 11%, and 9% of the landings, respectively). In the absence of CPUE data, the comparative trends of landings and price were employed as an indicator of the "status" of specific elasmobranch species. *Raja* spp., *Centrophorus granulosus*, *Mustelus* spp., *Torpedo* spp., and *Squatina* spp. displayed indications of possible overexploitation, and they merit the focus of future research.

<sup>1</sup> Nunes, M. L., I. Baptista, R. M. Campos, and A. Viegas. 1989. Aproveitamento e valorização de algumas espécies de tubarão. Relat. Téc. Cient. INIP, Lisboa, 7, 38 p.

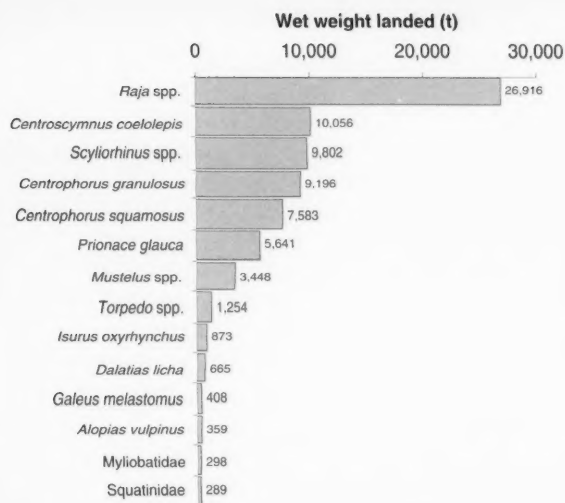


Figure 1.—Distribution of catch (wet weight landed) for each of the 14 most heavily landed elasmobranch species (> 250 t) reported in the Portuguese commercial fishery between 1986 and 2001.

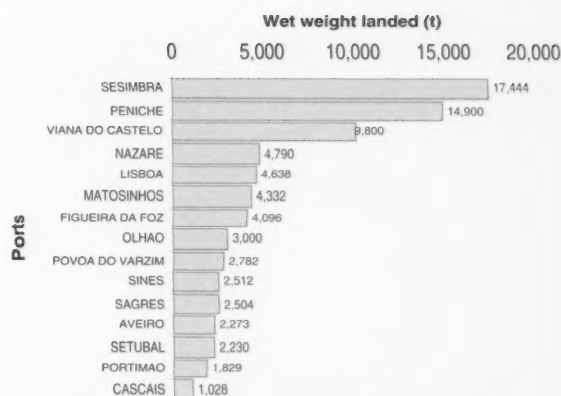


Figure 2.—Distribution of catch (wet weight landed) for each of the 15 ports with the heaviest landings (> 1,000 t) of elasmobranchs reported in the Portuguese commercial fishery between 1986 and 2001.

(Silva<sup>2,3,4</sup>, Silva and Pereira<sup>5</sup>, and Figueiredo et al.<sup>6</sup>). This paper provides an introductory overview of the commercial Portuguese elasmobranch fishery and its evolution over the period between 1986 and 2001 and suggests possible avenues of future research.

### Data Sources

The data for this study were obtained from the central commercial fishery authority for the Portuguese government

(Direção Geral das Pescas). Landed weights were totaled for each species, for all ports, for 1986–2001. Species whose landed weight exceeded 250 t are shown in Figure 1.

Landed weights were compiled by port for all species during the period. Ports with landings of >1,000 t are shown in Figure 2. Ports or regions with landings for a specific species >25% of the total landings of that species for all of Portugal, are shown in Figure 3. Annual species landings trends were further examined using a linear regression analysis (Table 1, Fig. 4–13).

Mean yearly price per kilogram (PPK) was calculated per species to examine changes in “demand” and the results of linear regression analysis are given in Table 2. Mean yearly PPK for all species was also calculated (Fig. 14).<sup>7</sup>

Changes in fishing “effort” during the study period were examined. The number of vessels registered to fish in Portuguese waters was totaled for each year between 1992 and 2000 and trends

were examined. (No data were available for 1986–1991.)

Yearly weight landings and mean yearly PPK's were compared to examine the current “status” of the 14 most heavily landed elasmobranch, i.e. the slopes of the regression analyses of yearly landings and mean yearly PPK's, for each species, were reviewed (Table 2), and those species exhibiting significant trends are shown in Figures 4–13.

### Catch and Effort History

During the 16-year study period, the total landed weight of elasmobranchs was 82,704 t, averaging 5,169 t ( $\pm 795$  t) per year. These landings represented 18 families, 29 genera, and 34 species of shark and ray (Table 1). The ten groups most often landed were *Raja* spp., *Centroscymnus coelolepis*, *Scyliorhinus* spp., *Centrophorus granulosus*, *Centrophorus squamosus*, *Prionace glauca*, *Mustelus* spp., *Torpedo* spp., *Isurus oxyrinchus*, and *Dalatias licha* (Fig. 1), and they accounted for 91.2% of the total weight landed (75,433 t).

Care should be taken when examining these results, as the fishermen often identified elasmobranchs by their common

<sup>2</sup> Silva, H. M. 1983. Preliminary studies of the exploited stock of kitefin shark *Scymnorhinus licha* (Bonnaterre, 1788) in the Azores. ICES/CM 1983/G:18, 13 p.

<sup>3</sup> Silva, H. M. 1987. An assessment of the Azorean stock of kitefin shark *Dalatias licha* (Bonnaterre, 1788). ICES/CM 1987/G:66, 10 p.

<sup>4</sup> Silva, H. M. 1988. Growth and reproduction of kitefin shark *Dalatias licha* (Bonnaterre, 1788) in Azorean waters. ICES/CM 1988/G:21, 15 p.

<sup>5</sup> Silva, A. A., and J. J. Pereira. 1999. Catch rates for pelagic sharks taken by the Portuguese swordfish fishery in the waters around the Azores, 1993–1997. ICCAT SCRS/98, 12 p.

<sup>6</sup> Figueiredo, I., M. J. Figueiredo, and O. Moura. 1995. Distribution, abundance and size composition of blackmouth catshark (*Galeus melastomus*) and small-spotted dogfish (*Scyliorhinus canicula*) on the slope of the Portuguese South and Southern West coasts. ICES/CM 1995/G:9, 38 p.

<sup>7</sup> PPK was converted from PTE (Portuguese Escudos) to US\$ (United States dollars) using the mean conversion rate for 1999 of 195 to 1.

name. Experience has demonstrated that the fishermen and fishery officials were accurate at identifying individual elasmobranch species. However, two taxa were notable for the way in which they were inappropriately recorded. First, 1.9% (or 1,564 t) of the total landings were attributed to the group "pleurotremata," a taxonomic term adopted for those shark species that fishermen could not identify accurately. Hence, the group "pleurotremata" was excluded from Figure 1. Second, 1.3% (or 1,036 t) of the total landings were attributed to *Oxynotus centrina*. The Portuguese common name for this species, "peixe porco," is also the common name for a local teleost, *Balistes carolinensis*. Hence, the data for *Oxynotus centrina* was considered unreliable and was also excluded from Figure 1. Finally, 290 t of elasmobranch liver and 2,101 t of elasmobranch oil were also landed during the period between 1986 and 2001. These totals are still included in the grand total of 82,704 t.

The ten ports with the highest landings were Sesimbra, Peniche, Viana do Castelo, Nazaré, Lisboa, Matosinhos, Figueira da Foz, Olhão, Póvoa do Varzim, and Sines (Fig. 2). These ports accounted for 82.6% of the landings, or 68,295 t. The remaining 17.4% of the total weight landed was drawn from an additional 59 ports scattered throughout continental Portugal.

Some elasmobranch species were landed along much of the coast of Portugal. These included *Raja* spp., *Scyliorhinus* spp., *Torpedo* spp., *Isurus oxyrinchus*, *Galeus melastomus*, *Dasyatidae*, *Hexanchus griseus*, *Lamna nasus*, *Cetorhinus maximus*, *Echinorhinus brucus*, and *Etmopterus* spp. (Fig. 3). Other elasmobranch species were often caught in specific regions. Total annual landings have been decreasing since 1990 and remained below 5,000 t after 1993 (Fig. 14).

Yearly landings for *Centroscyrmus coelolepis* demonstrated a significant increase over the test period (Fig. 5, Table 2). Significant increases in yearly landings were also observed for *Scyliorhinus* spp., and *Galeus melastomus* (Fig. 6, 12, and Table 2). Significant

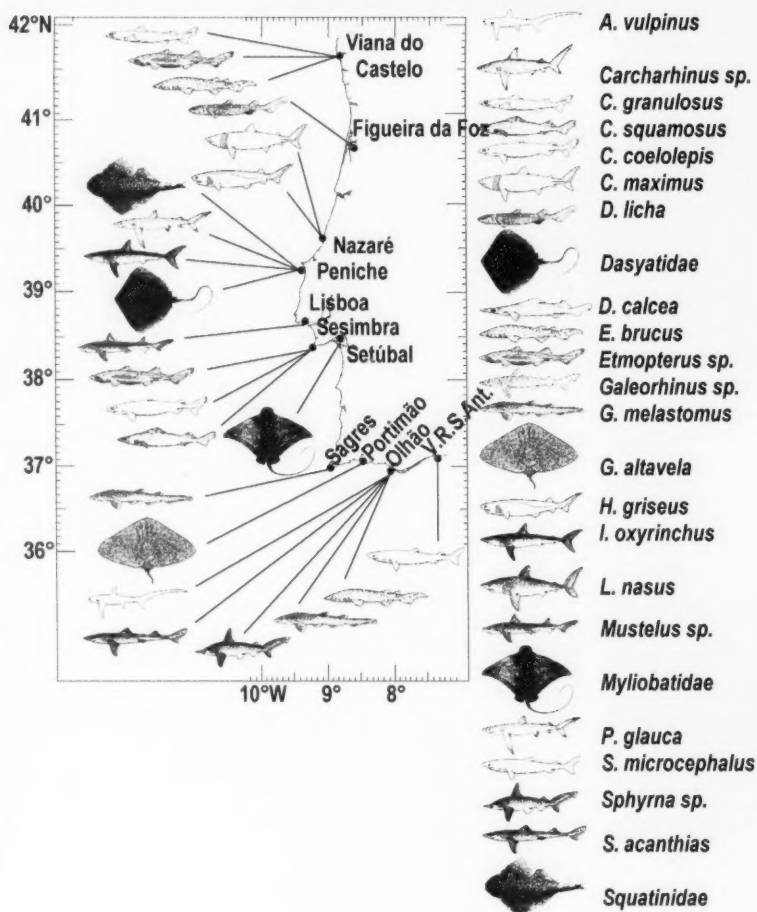


Figure 3.—Distribution of heavy elasmobranch landings by port (where species weight landed is >25% of the total species weight landed for all of continental Portugal), for the Portuguese commercial fishery, between 1986 and 2001.

decreases in yearly landings were observed for *Raja* spp., *Centrophorus granulosus*, *Mustelus* spp., *Torpedo* spp., and *Squatina* spp. (Fig. 4, 7, 10, 11, 13, and Table 2).

As would be expected, mean yearly PPK values increased over the test period for all species, reflecting a price increase associated with inflation (Table 2). However, some species demonstrated marked average annual increases of over 10% per annum. Annual average PPK increases were 10% for *Raja* spp., 8% for *Centroscyrmus coelolepis*, 8% for *Scyliorhinus* spp., 12% for *Centrophorus*

*granulosus*, 9% for *Centrophorus squamosus*, 17% for *Prionace glauca*, 10% for *Mustelus* spp., 12% for *Torpedo* spp., 9% for *Isurus oxyrinchus*, 22% for *Dalatias licha*, 16% for *Galeus melastomus*, 14% for *Alopias vulpinus*, 8% for *Myliobatidae*, and 20% for *Squatina* spp. These PPK increases exceeded the official annual average inflation rate in Portugal during the same period of 4.64%  $\pm$  0.92% (Pereira<sup>8</sup>).

<sup>8</sup> Pereira, A. E. 2000. A inflação e o índice de preços no consumidor. Dossiers didáticos. Instituto Nacional de Estatística, Lisboa, 21 p.

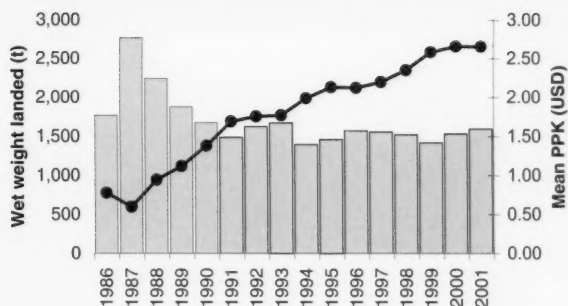


Figure 4.—Annual wet weight landings for *Raja* spp. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

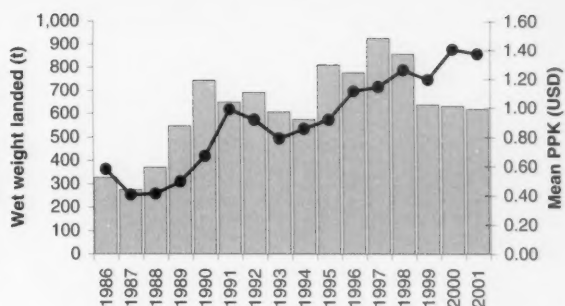


Figure 5.—Annual wet weight landings for *Centroscymnus coelolepis*. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

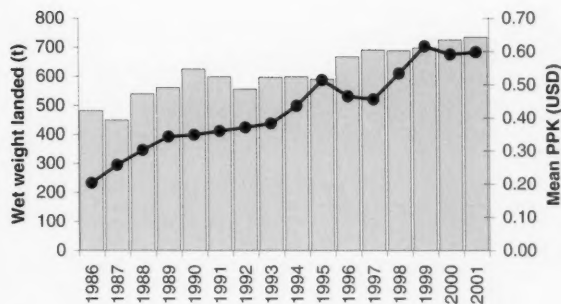


Figure 6.—Annual wet weight landings for *Scyliorhinus* spp. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

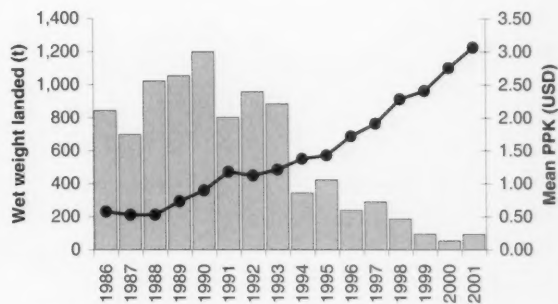


Figure 7.—Annual wet weight landings for *Centrophorus granulosus*. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

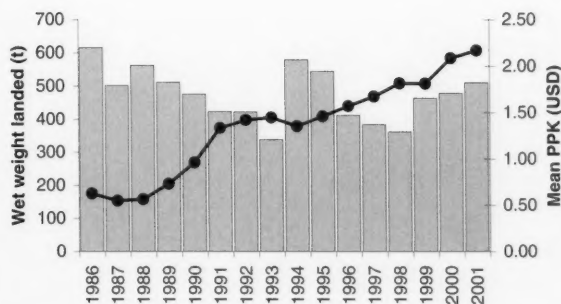


Figure 8.—Annual wet weight landings for *Centrophorus squamosus*. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

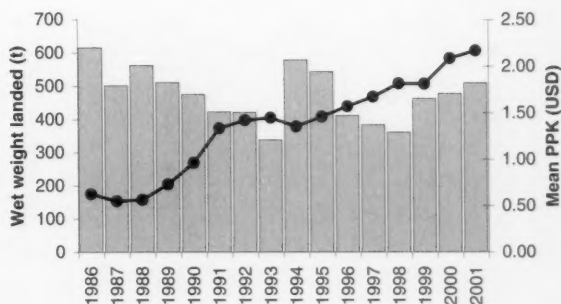


Figure 9.—Annual wet weight landings for *Prionace glauca*. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

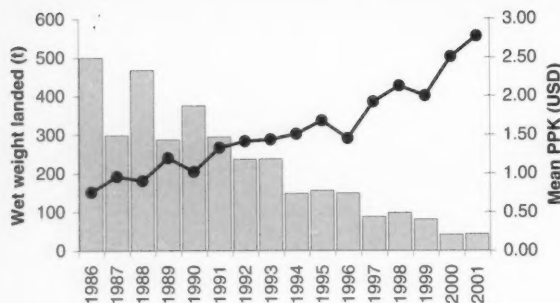


Figure 10.—Annual wet weight landings for *Mustelus* spp. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

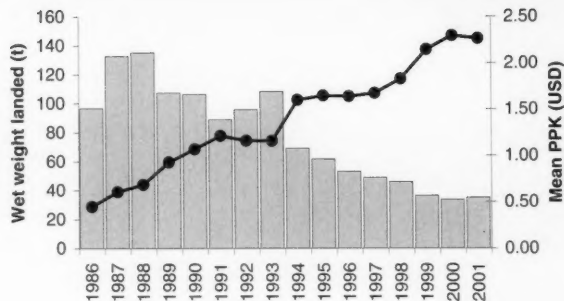


Figure 11.—Annual wet weight landings for *Torpedo* spp. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

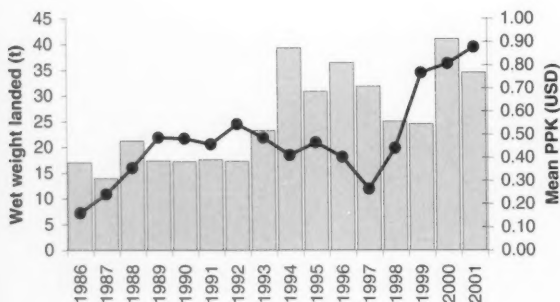


Figure 12.—Annual wet weight landings for *Galeus melastomus*. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

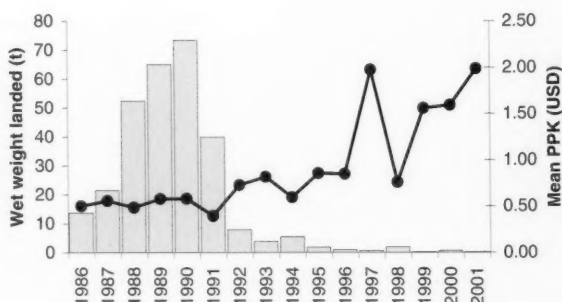


Figure 13.—Annual wet weight landings for Squatinidae. Mean annual PPK (price per kilogram in US\$) is represented by solid line.

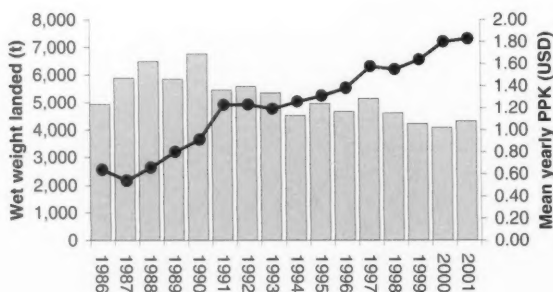


Figure 14.—Annual elasmobranch landings reported in the Portuguese commercial fishery between 1986 and 2001. Mean annual PPK (price per kilogram in US\$) is represented by the solid line.

Mean yearly PPK for all elasmobranch landings increased from 0.64 in 1986 to 1.83 in 2001; a mean yearly increase of

7.88%  $\pm$  12% (Fig. 14). Interestingly, mean yearly PPK briefly peaked in 1991. During the previous year, total landings

reached a maximum peak at 6,768 t and then dropped by 19.5% to 5,451 t (Fig. 14). The increased mean yearly PPK in 1991 could therefore possibly reflect an increased demand for elasmobranch fishes during that year (Fig. 14) which was not echoed by sufficient landings.

The total number of registered fishing vessels decreased from 6,864 in 1992 to 5,013 in 2000, a decrease of 27% or a mean yearly decrease of 3.84%  $\pm$  1.85%. During the same period, landings of *Scyliorhinus* spp. increased (from 556 to 725 t, an increase of 30%) (Fig. 6). This was repeated for *Centrophorus squamosus* (from 422 to 478 t, an increase of 13%) (Fig. 8), *Galeus melastomus* (from 17 to 41 t, an increase of 137%) (Fig. 12), and *Alopias vulpinus* (from 13 to 15 t, an increase of 12%).

During the same period (i.e. 1992–2000), landings of *Centrophorus granulosus* decreased at a much greater rate than the total vessels registered (from 958 to 54 t, a decrease of 94%) (Fig. 7). Similar observations were made for *Prionace glauca* (from 374 to 316 t, a decrease of 16%) (Fig. 9), *Mustelus* spp. (237 to 41 t, a decrease of 83%) (Fig. 10), *Torpedo* spp. (from 96 t to 34 t, a decrease of 65%) (Fig. 11), *Dalatias licha* (from 25 t to 5 t, a decrease of 80%), *Myliobatidae* (from 15 t to 9 t, a decrease of 43%), and *Squatinae* (from 8 t to 1 t, a decrease of 92%) (Fig. 13).

Table 1.—Species of elasmobranchs recorded in Portuguese waters, indicating: species with confirmed landings (\*) and unconfirmed landings (?) by the commercial fishery (after Sanches, 1986).

Order	Species	Order	Species
Lamniformes	? <i>Alopias superciliosus</i>	Squaliformes (cont.)	* <i>Somniosus microcephalus</i>
	* <i>Alopias vulpinus</i>		<i>Somniosus rostratus</i>
	* <i>Carcharodon carcharias</i>		<i>Squaliolus laticaudus</i>
	* <i>Cetorhinus maximus</i>		* <i>Squalus acanthias</i>
	* <i>Isurus oxyrinchus</i>		? <i>Squalus blainvilliei</i>
	* <i> Lamna nasus</i>	Hexanchiformes	<i>Chalmydoselachus anguineus</i>
	? <i>Mitsukurina owstoni</i>		<i>Heptranchias perlo</i>
	* <i>Odontaspis ferox</i>		* <i>Hexanchus griseus</i>
	* <i>Odontaspis noronhai</i>	Pristiiformes	<i>Pristis pristis</i>
Carchariniformes	* <i>Apristurus laurussonii</i>	Squatiniiformes	* <i>Squatina squatina</i>
	? <i>Carcharhinus falciformis</i>	Torpediniiformes	? <i>Torpedo marmorata</i>
	? <i>Carcharhinus limbatus</i>		? <i>Torpedo nobiliana</i>
	? <i>Carcharhinus longimanus</i>		? <i>Torpedo torpedo</i>
	? <i>Carcharhinus obscurus</i>	Rajiformes	* <i>Amblyraja radiata</i>
	? <i>Carcharhinus plumbeus</i>		? <i>Dasyatis centroura</i>
	* <i>Galeorhinus galeus</i>		? <i>Dasyatis pastinaca</i>
	* <i>Galeus melastomus</i>		<i>Dipturus batis</i>
	* <i>Mustelus asterias</i>		<i>Dipturus lineatus</i>
	* <i>Mustelus mustelus</i>		<i>Dipturus oxyrinchus</i>
	* <i>Prionace glauca</i>		* <i>Gymnura altavela</i>
	* <i>Pseudotriakis microdon</i>		* <i>Leucoraja circularis</i>
	* <i>Rhizoprionodon acutus</i>		* <i>Leucoraja fullonica</i>
	* <i>Scyliorhinus canicula</i>		* <i>Leucoraja naevus</i>
	? <i>Scyliorhinus stellaris</i>		<i>Manta birostris</i>
	* <i>Sphyrna zygaena</i>		<i>Mobula mobular</i>
Squaliformes	* <i>Centrophorus granulosus</i>		* <i>Myliobatis aquila</i>
	* <i>Centrophorus squamosus</i>		* <i>Pteromyliobatis bovinus</i>
	* <i>Centroscyrmus coelolepis</i>		? <i>Raja asterias</i>
	* <i>Centroscyrmus crepidater</i>		? <i>Raja brachyura</i>
	* <i>Centroscyrmus cryptacanthus</i>		* <i>Raja clavata</i>
	* <i>Dalatias licha</i>		? <i>Raja maderensis</i>
	* <i>Deania calcea</i>		? <i>Raja microcellata</i>
	* <i>Echinorhinus brucus</i>		? <i>Raja miraletus</i>
	* <i>Etmopterus pusillus</i>		? <i>Raja montagui</i>
	* <i>Etmopterus spinax</i>		* <i>Raja undulata</i>
	* <i>Oxynotus centrina</i>		* <i>Rhinobatos rhinobatos</i>
	* <i>Scymnodon obscurus</i>		* <i>Rostrolatja alba</i>
	* <i>Scymnodon ringens</i>		

Table 2.—Slopes of species landings and price per kilogram (PPK) as estimated using a linear regression analysis for each of the 16 most heavily landed elasmobranchs reported in the Portuguese commercial fishery between 1986 and 1999. Species with significance of F value < 0.05 (marked with \*) displayed a significant change over time for the parameter analyzed. This change was an increase if the corresponding slope was positive and a decrease if the corresponding slope was negative.

Species	Landings (kg/year)				PPK (US\$/year)				n	Category <sup>1</sup>
	Slope	r <sup>2</sup>	Sig. F	Rem.	Slope	r <sup>2</sup>	Sig. F	Rem.		
<i>Raja</i> spp.	-47.413	0.41	0.01	*	0.13	0.960	0.00	*	16	III
<i>Centroscyrmus coelolepis</i>	24.983	0.42	0.01	*	0.06	0.893	0.00	*	16	II
<i>Scyliorhinus</i> spp.	16.400	0.87	0.00	*	0.02	0.944	0.00	*	16	II
<i>Centrophorus granulosus</i>	-72.067	0.75	0.00	*	0.16	0.946	0.00	*	16	III
<i>Centrophorus squamosus</i>	-6.461	0.15	0.14		0.10	0.941	0.00	*	16	I
<i>Prionace glauca</i>	10.733	0.23	0.06		0.05	0.744	0.00	*	16	I
<i>Mustelus</i> spp.	-28.265	0.88	0.00	*	0.11	0.909	0.00	*	16	III
<i>Torpedo</i> spp.	-6.731	0.85	0.00	*	0.12	0.970	0.00	*	16	III
<i>Isurus oxyrinchus</i>	-238	0.00	0.80		0.12	0.635	0.00	*	16	I
<i>Dalatias licha</i>	-9.716	0.44	0.00	*	0.06	0.701	0.00	*	16	III
<i>Galeus melastomus</i>	1.434	0.58	0.00	*	0.03	0.508	0.00	*	16	II
<i>Alopias vulpinus</i>	-755	0.02	0.57		0.07	0.816	0.00	*	16	I
<i>Myliobatidae</i>	-164	0.02	0.64		0.05	0.830	0.00	*	16	I
<i>Squatinae</i>	-3.434	0.42	0.01	*	0.09	0.643	0.00	*	16,00	III

<sup>1</sup> Category I: significant changes were not discernible for landings and / or price and therefore the status of the species was undetermined; Category II: significantly increasing landings and significantly increasing price were interpreted as a species subjected to possible commercial exploitation; Category III: significantly decreasing landings and significantly increasing price were interpreted as a species subjected to possible risk of over-fishing.

Landings and mean yearly PPK for *Centroscyms coelolepis* both increased significantly over the period of study (Fig. 5 and Table 2). This observation was repeated for *Scyliorhinus* spp., and *Galeus melastomus* (Fig. 6, 12, and Table 2).

Landings for *Raja* spp. decreased significantly, while mean yearly PPK increased significantly over the period of study (Fig. 4 and Table 2). This observation was repeated for *Centrophorus granulosus*, *Mustelus* spp., *Torpedo* spp., and Squatinidae (Fig. 7, 10, 11, and 13 and Table 2).

### Discussion

Between 1986 and 1996, the Portuguese commercial fishing fleet landed 2,437,700 t of fishes and invertebrates, a mean of  $221,609 \pm 4,827$  t per annum (DGPA, 1998). During the same period, 62,333 t of elasmobranchs were landed, constituting 2.56% of the total catch. During the period of this study (1986–2001), mean annual elasmobranch landings were  $5,169 \pm 795$  t. By comparison, Indonesia recorded mean annual landings of 70,000 t between 1987 and 1991. Mexico, the United States, and the Philippines reported mean annual landings of 34,000, 25,000, and 18,000 t, respectively (Bonfil, 1994). By comparison, other European nations such as Spain, Italy, and Norway reported mean annual landings of 18,000, 10,000, and 8,000 t between 1987 and 1991, respectively (Bonfil, 1994).

Information about the distribution of elasmobranch species throughout Portuguese waters has not been previously available except for limited data provided by IPIMAR research surveys (Figueiredo<sup>9,10</sup>). Figure 3 indicates that some elasmobranch species were landed

relatively heavily at specific ports, suggesting some relationship between species distribution and geographic location. This possibility is supported by the fact that fishing vessels rarely strayed far from their home port during normal operation (i.e. <20 km except in exceptional circumstances). In addition, modern fishing ports in Portugal have grown up around traditional fishing villages, and there is little evidence to suggest that local demand or infrastructure resulted in heavier landings of specific elasmobranch species in a given region.

One possible reason for the regional difference in elasmobranch landings is an interplay between the distribution of these species throughout Portuguese waters as dictated by their ecology, local bathymetry, and the specificity of different fishing techniques.

The possible effect of bathymetry and fishing techniques on the capture of specific species may be evidenced by the higher landings of *Raja* spp. and *Gymnura altavela* from the port of Olhão. In this region of Portugal, the 1,000 m isobath is approximately 58.8 km from the coastline (Viriato et al., 1996). The shallower conditions in this area favor crustacean bottom trawlers, one of the principal sources of these benthic elasmobranch species.

Similarly, the largest bottom longline fleet in Portugal operates from the port of Sesimbra, located very close to the edge of the continental shelf. Here, the 1,000 m isobath is only 13.7 km from the coastline (Viriato et al., 1996). Vessels from Sesimbra are large and able to operate down to 3,000 m, while vessels from other ports are generally smaller and are seldom able to operate below 1,000 m. During a survey of deep-sea fishes by the Portuguese Marine Research Institute (IPIMAR), one of the authors (Correia<sup>11</sup>) observed that *Centroscyms coelolepis* was very rarely caught at depths shallower than 800 m. Depth of fishing operation could therefore account for the heavier landings of the deep-sea sharks *Centroscyms coelolepis* and

*Centrophorus squamosus* in this region. Finally, the port of Peniche operated a large surface long line fleet, possibly accounting for the relatively higher landings of *Prionace glauca* and *Isurus oxyrinchus*, and the lower landings of deep-sea sharks.

These examples appear to support the conjecture that the use of specific fishing techniques and operation depths could have been species selective and account for the composition of landings at specific geographic locations. Unfortunately, there is insufficient information available to draw solid conclusions about habitat preferences (Capapé, 1985). In addition, there is a relative lack of literature on the topography of Portuguese waters below 400 m (Viriato et al., 1996). In an effort to better understand the Portuguese EEZ and improve the management of marine resources, the IPIMAR is currently conducting topography surveys along the Portuguese coastline, with the ultimate objective of mapping the sea floor down to a depth of 1,000 m.

The increase in landings demonstrated between 1992 and 1995 (Fig. 14) could be the result of increasing demand. One possible scenario is that an interest in marketing elasmobranchs was rekindled when deep-sea sharks were caught in large numbers as bycatch of the “booming” *Aphanopus carbo* fishery. When the value of the flesh was recognized and demand grew, elasmobranchs may have then been increasingly targeted during the late 1980’s and early 1990’s.

There have been no CPUE (catch per unit effort) studies for the Portuguese commercial elasmobranch fishery. In the absence of CPUE data, another approach was used to try and get some indication of fishery trends. Changes in the annual landings of each species were compared with changes in a “demand” indicator—mean annual price per kilogram. This allowed some cautious inferences about the “status” of each elasmobranch species. Every species was ranked according to three distinct categories: category I, where significant changes were not discernible for landings and/or price and therefore the status of the species was undetermined; category II, where significantly increasing landings

<sup>9</sup> Figueiredo, I., M. J. Figueiredo, and O. Moura. 1995. Distribution, abundance and size composition of blackmouth catshark (*Galeus melastomus*) and small spotted dogfish (*Scyliorhinus canicula*) on the slope of the Portuguese south and southern west coasts. Int. Council Explor. Sea, Demersal Fish Committee, CM 1995 (G:9), 38 p.

<sup>10</sup> Figueiredo, M. J., I. Figueiredo, and J. Correia. 1996. Caracterização geral dos recursos de profundidade em estudo no IPIMAR. Relat. Cient. Téc. Inst. Port. Invest. Marit. 21, 50 p.

<sup>11</sup> Correia, J. 2003. Oceanário de Lisboa, Doca dos Olivais 1990–005 Lisboa, Portugal.

and significantly increasing price were interpreted as a species subjected to possible commercial exploitation; and category III, where significantly decreasing landings and significantly increasing price were interpreted as a species subjected to possible risk of over-fishing (Table 2). This theoretical approach was supported by the observation that mean yearly price per kilogram briefly peaked in 1991 while landings slumped, potentially reflecting an increased demand by the consumers of elasmobranch fishes during that year.

In general, annual elasmobranch landings decreased over the period between 1986 and 2001. During the same period of time, teleost and invertebrate landings also decreased suggesting that there had not been an obvious shift in target taxa (DGPA, 1998). One reason for this decline was probably as a response to a directive from the European Union to reduce the size of fishing fleets throughout Europe (DGPA, 1998). Between 1992 and 1999 the fishing fleet decreased by 23.1%. This was paralleled by a 23.5% decline in total landings for all species of fishes and invertebrates. However, during the same period elasmobranch landings decreased by 32.7% suggesting that a reduction in the size of the fishing fleet alone did not account for the decline in elasmobranch landings.

Mean price per kilogram increased over the period of study for all of the 14 species examined. This result probably reflects, in part, a natural price increase due to inflation. However, all displayed rates increased well in excess of the official rate of inflation. This suggests that an increased consumer demand was driving the price of elasmobranch meat and by-products higher.

*Centroscymnus coelolepis* and *Scyliorhinus* spp. demonstrated significantly increased landings and a significantly increased price over the period of study (category II, Table 2). As these species may be subjected to commercial exploitation, their stocks should be monitored closely, allowing the formulation of adequate management strategies.

The rate at which the fishing fleet decreased in size was greatly exceeded by the rate at which landings decreased

for all category III species (i.e. *Raja* spp., *Centrophorus granulosus*, *Mustelus* spp., *Torpedo* spp., and *Squatina* spp.). As such, it is possible to suggest that decreasing "effort" alone, did not account for the decreased landings observed. This conjecture is supported by the fact that some species demonstrated increased landings over the same period of study (e.g. *Centroscymnus coelolepis*, *Scyliorhinus* spp., *Prionace glauca*, and *Galeus melastomus*). One could therefore very cautiously suggest that the category III species are at risk of being over-exploited and are in need of immediate management.

Interestingly, the five category III species diverge somewhat phylogenetically. It could be expected that species showing signs of over-exploitation would share common life-history traits, such as low fecundity and long gestation periods (Natanson and Cailliet, 1986). However, *Mustelus* spp. is often associated with higher rates of reproduction (Yudin and Cailliet, 1990). The fact that this species was associated with other category III animals is a motive for concern. It either casts doubt on the interpretation of landings and price trends, or alternatively, it could indicate very strong fishing pressures, or even the removal of the sexually mature size class, as the cause of decline in this species.

In conclusion, it appears as if *Centroscymnus coelolepis*, *Scyliorhinus* spp., *Prionace glauca*, and *Galeus melastomus* are currently being heavily targeted, while *Raja* spp., *Centrophorus granulosus*, *Mustelus* spp., *Torpedo* spp., and *Squatina* spp. may be at risk of over-fishing, either within localized fishing grounds, or throughout the EEZ. These species certainly merit the focus of future research.

The limitations of price per kilogram and registered fishing vessels as indicators of "demand" and "effort" should be carefully considered when examining the conclusions of this article. Clearly, CPUE studies are required for the development of robust management plans. However, in the absence of CPUE data, perhaps the relationship between PPK and landings in historical data sets can be used as a useful early warning indicator of species at possible risk of over-exploitation.

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## Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

### The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

### Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and

double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

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In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

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Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

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